Three Essays on Financial Intermediation in the Open Economy

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To my grandparents

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Abstract

This thesis examines the role of financial frictions for international business cycles and policymaking in open economies. The analyses are based on two-country DSGE models with leverage-constrained financial intermediaries who can extend credit to home and foreign firms. In the first essay, I assess the role of banks' balance sheet exposure to foreign assets for the cross-country transmission of shocks. It is shown that this role depends on the nature of a particular shock. Balance sheet exposure is essential for global co-movement in the case of capital quality shocks but does not play a decisive role conditional on other types of shocks. In the second essay, I analyze whether it is desirable to use unconventional monetary policy to stabilize country-specific shocks in a monetary union with financial frictions. It is shown that country-specific rules are not necessarily associated with higher welfare from the viewpoint of a structurally symmetric union. In particular, when the indicators of the rules are highly correlated, union-wide rules are preferable. In the third essay, I provide an explanation for the well-known puzzle that international consumption risk-sharing is relatively low compared to what theoretical models would predict given the high level of international financial-market integration. In particular, it is shown that a portfolio chosen by financial intermediaries instead of households does not necessarily yield the highest possible degree of international consumption risk-sharing.

Zusammenfassung

Gegenstand dieser Dissertation ist die Rolle von Finanzmarktfriktionen für internationale Konjunkturzyklen und daraus resultierende Politikimplikationen. Die Analysen basieren auf Zwei-Länder DSGE Modellen mit international agierenden Finanzintermediären. Im ersten Aufsatz wird untersucht, ob der Anteil ausländischer Kapitalanlagen am Bankvermögen eine Rolle für die Übertragung von Schocks zwischen Ländern spielt. Es kann gezeigt werden, das dies von der Art des jeweiligen Schocks abhängt: Ein höherer Anteil ausländischer Kapitalanlagen führt nur dann zu einer höheren Synchronisierung von Konjunkturzyklen wenn letztere durch sogenannte Capital-Quality-Schocks verursacht werden. In zweiten Aufsatz untersuche ich, ob es wohlfahrtssteigernd ist, unkonventionelle Geldpolitik zur Stabilisierung länderspezifischer Schocks in einer strukturell symmetrischen Währungsunion mit Finanzmarktfriktionen zu verwenden. Es wird gezeigt, das dies nicht immer der Fall ist: Wenn die Politikregeln auf Indikatoren beruhen, die hochkorreliert zwischen den Ländern sind, führen unionsweite Regeln zu höherer Wohlfahrt als länderspezifische. Der dritte Aufsatz liefert eine Erklärung für relativ geringe internationale

Risikoteilung, verglichen mit dem was übliche Modelle, basierend auf dem hohen Grad an Finanzmarktintegration, vorhersagen: Ein internationales Portfolio, was von Finanzintermediären anstelle von Haushalten gewählt wurde, führt im gegebenen Modell zu suboptimaler Risikoteilung.

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Chapter 1

Introduction

The last decade has revealed a number of new challenges for macroeconomic research. The financial crisis which started in 2007 reminded us starkly of the great importance of financial factors for the real economy. In particular, a salient feature of the crisis was a serious interruption of financial intermediation (see, e.g., Gertler and Kiyotaki, 2011; Brunnermeier, 2009). This has motivated many macroeconomists to incorporate banks into otherwise standard general equilibrium models in order to understand their role for business cycles.[1] In addition, the fact that a shock originating in the U.S. subprime mortgage market was promptly followed by recessions in most countries of the world (c.f. Imbs, 2010), drew attention to the substantial increase in cross-border holdings of financial assets and liabilities since the early 1990s (cf. Lane and Milesi-Ferretti, 2007) and its potential role for the fast-paced spreading of the crisis. Hence, to better understand the role of financial market integration for international business-cycle comovement, open economy models started to frequently incorporate a financial sector.[2] On the policy side, the financial crisis and the subsequent global recession induced central banks around the world to engage into a number of unprecedented unconventional policy interventions, with the aim to redress interrupted financial markets. This led to a new strand of macroeconomic literature, assessing domestic as well as international effects of credit facilities implemented by central banks.[3]

This thesis contributes to the understanding of the role of financial intermediaries for international business cycles (chapters 2 and 4). In doing so, it also proposes a

[1] See, e.g., Gertler and Kiyotaki (2011), Gertler and Karadi (2011), Cúrdia and Woodford (2011), Gerali et al. (2010), Meh and Moran (2010), to name a few.

[2] While earlier contributions such as Devereux and Yetman (2010), Dedola and Lombardo (2012) and Devereux and Sutherland (2011b) treat financial intermediaries as a veil, e.g., Kollmann et al. (2011), Guerrieri et al. (2012), Dedola et al. (2013), Poutineau and Vermandel (2015) and Dräger and Proaño (2018) explicitely model internationally diversified financial intermediaries.

[3] While, e.g., Gertler and Kiyotaki (2011), Gertler and Karadi (2011), Cúrdia and Woodford (2011) and Del Negro et al. (2011) frame their analyses in the context of closed economy models, e.g., Dedola et al. (2013) and Nuguer (2016) also take into account the global reach of unconventional monetary policy measures.

solution to one of the key puzzles in international macroeconomics – the fact that consumption risk-sharing is relatively low despite the high level of financial market integration (chapter 4). Furthermore, it contributes to the understanding of the welfare effects of unconventional monetary policy in an international context, more specifically, in the context of a monetary union (chapter 3).

The analyses are based on two-country DSGE models which incorporate a banking sector à la Gertler and Kiyotaki (2011) and Gertler and Karadi (2011). This or slightly modified setups of the banking sector have been used in various accounts of the recent financial crisis. Following this practice ensures comparability with existing literature. The two-country version of the model developed in this thesis features final goods market integration as well as asset and deposit market integration. Integration of asset markets is modeled by assuming that intermediaries can purchase financial claims on goods producing firms at home and abroad. In chapters 2 and 4, I assume that banks endogenously choose the portfolio composition with the purpose of optimally hedging country-specific banking risk (see, e.g., Dedola et al., 2013). I solve the optimal portfolio choice problem using the method proposed by Devereux and Sutherland (2007; 2008; 2011a). In chapter 3, I model international portfolio choice by means of a CES function which facilitates a second-order approximation of the model which is necessary for welfare analyses.[4]

A common explanation of the global scale of the crisis reads that a drop in the value of some assets related to the U.S. subprime mortgage market instantly forced leveraged investors around the globe – holding this particular type of assets – to deleverage by selling assets across the board. This caused a general decline in asset prices, aggravating the initial events and spreading the crisis to further sectors and countries. The explanation suggests that there are two sources of international comovement in real and financial variables: First, balance sheet exposure to foreign assets enables a direct transmission of shocks across borders via the asset side of banks' balance sheets. Second, regardless of the degree of balance sheet exposure in quantitative terms, price equalization in integrated financial markets leads to international business-cycle comovement. The theoretical model I develop in chapter 2 incorporates both channels. Nevertheless, I show that it is conditional on the type of shock whether the balance sheet channel plays an important role and, hence, whether the degree of direct exposure to foreign assets is crucial for international comovement in real and financial variables. In particular, the share of foreign assets in banks' portfolios is essential for global comovement in the case of capital quality shocks but does not play a decisive role for cross-country correlations conditional on technology shocks and shocks to the net wealth of banks. The latter two have

[4]The usage of the CES function to determine international portfolios has become more and more popular in recent years. In combination with a different setup of the banking system it has been used by, e.g., Auray et al. (2016), Poutineau and Vermandel (2015), Brzoza-Brzezina et al. (2015) and Dräger and Proaño (2018).

been at centerstage in previous theoretical accounts of the role of balance sheet exposure for global comovement (see, e.g., Dedola and Lombardo, 2012; Yao, 2012; Devereux and Yetman, 2010).

As Draghi (2013) phrased it, "[t]he particular challenge of the ECB is to operate in a multi-country environment: one monetary policy for 17 countries that constitute our currency union". This is a particular challenging task, given that business cycles between member countries are less than perfectly correlated. So far, most theoretical accounts of unconventional monetary policy in open economies assume country-specific monetary authorities interested in maximizing their own welfare. To provide orientation for policymakers in a monetary union, chapter 3 of this thesis expands existing literature by analyzing whether unconventional monetary policy can and should be used to stabilize country-specific shocks in a monetary union. I show that rules based upon country-specific indicators are not necessarily associated with higher welfare. In particular, whenever the central bank resorts to indicators, which are highly correlated between countries, union-wide rules are preferable. The intuition behind this result is second-best reasoning: To the extent that financial frictions cannot be fully eliminated, a reduction in volatility has positive and negative effects on welfare. The cross-country correlation of the indicators affects the degree of volatility associated with different rules and also influences the welfare effects of volatility which can explain the results. To my knowledge, there is only one paper by Tischbirek (2016) which addresses this kind of question. However, he focuses on the effects of government debt purchases on fiscal policies and uses a model which does not feature financial frictions.

An important function of international financial markets is to allow countries to insure themselves against country-specific risk. Hence, given the substantial increase in financial market integration in the last three decades, it is surprising, that consumption risk-sharing is modest at best and has increased much less throughout the same period of time (e.g., Kose et al., 2009). In the fourth chapter of this thesis, I built upon the model developed in chapter 2 and propose an explanation for this international risk-sharing puzzle: The – quite realistic – assumption that financial intermediaries choose the international portfolio instead of households can account for relatively low consumption risk-sharing compared to what could be achieved at the given level of financial market integration. This can be explained with the presence of a financial friction which drives a wedge between the incentives of households and financial intermediaries. As households are primarily concerned about consumption risk, a portfolio optimally chosen by households would coincide with the portfolio which yields the highest possible degree of consumption risk-sharing. In my model, banks are owned by households, hence, they internalize the objectives of households. However, due to an agency problem between bankers and depositors, they have an additional motive, namely the maximization of net wealth. Therefore, unless consumption and net worth fluctuations are perfectly correlated, financial intermediaries choose a portfolio which deviates from the one which maximizes consumption risk-sharing. These results are in line with those of Maggiori (2017), who shows that the existence of a financial friction, which introduces an additional motive for bankers, can account for several empirical findings related to risk-sharing between financially asymmetric countries. The results suggest a role for macroprudential policy in improving international consumption risk-sharing. I show that while a direct reduction of the financial friction has a positive impact on international consumption risk-sharing, the introduction of a countercyclical capital buffer does not have the same desirable consequences.

Chapter 2

Banks' Balance Sheets and the International Transmission of Shocks

Abstract

I propose a theoretical framework to think about the global comovement in real and financial variables during the recent financial crisis. The framework is used to address one question in particular: What is the role of banks' balance sheet exposure to foreign assets for the international transmission of country-specific shocks? I show that this role depends on the nature of the shock: Balance sheet exposure is essential for global comovement in the case of capital quality shocks but does not play a decisive role for cross-country correlations conditional on other shocks, e.g., technology shocks.

Keywords: International Business Cycles, Financial Frictions, Capital Quality Shocks, Consumption Risk Sharing, Portfolio Choice
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2.1 Introduction

The recent economic crisis with its origin in the U.S. financial sector has been characterized by an unprecedented global comovement in real as well as financial variables. Given the substantial increase in cross-border holdings of financial assets and liabilities since the early 1990s (see, e.g., Lane and Milesi-Ferretti, 2007), a common explanation of the global scale of the crisis is centered around international balance sheet exposure of highly leveraged financial institutions: A drop in the value of some assets related to the U.S. subprime mortgage market forced balance sheet constrained investors around the globe – holding similar portfolios – to deleverage by selling assets across the board. This caused a general decline in asset prices, aggravating the initial events and spreading the crisis to other sectors and other countries.

This paper assesses whether the degree of global comovement in real and financial variables is directly linked to the degree of banks' balance sheet exposure to foreign equity. To this end, I set up a two-country real DSGE model featuring leverage-constrained financial intermediaries modeled as in Gertler and Karadi (2011) and Gertler and Kiyotaki (2011) who hold risky claims on home and foreign capital as in Dedola et al. (2013) and Carniti (2012). I use this framework to analyze a type of shock which has recently gained importance in the business-cycle literature due to its ability to capture the broad dynamics of the subprime crisis (Gertler and Karadi, 2011) – a shock to the quality of capital. I find that for capital quality shocks, a sufficiently high share of foreign assets in banks' portfolios leads home and foreign output to move into the same direction. On the contrary, the degree of balance sheet exposure only plays a minor role in the transmission of technology shocks and shocks to the net worth of bankers – shocks which have been at centerstage in previous accounts of the role of balance sheet exposure for global comovement (see, e.g., Dedola and Lombardo, 2012; Yao, 2012; Devereux and Yetman, 2010). This is an interesting result as it suggests that we can only assess the consequences of the substantial increase in cross-border asset holdings for international comovement if we find out which shocks are currently the most important drivers of business cycles.

How is it possible that balance sheet exposure matters for the transmission of capital quality shocks but not for other shocks? A capital quality shock directly reduces the value of the corresponding assets in banks' balance sheets whereas technology shocks and net wealth shocks reach the asset side of balance sheets mainly via asset prices, which are equalized through international arbitrage in this kind of model.

Recently, capital quality shocks have been given much attention in the closed economy literature, as they can reproduce a comovement of real and financial variables very close to the one observed since the beginning of the 'Great Recession' of 2008-2009 (see, e.g., Furlanetto and Seneca, 2014; Gertler and Karadi, 2011; Gertler and Kiyotaki, 2011). Furthermore, various empirical studies show that this kind of shock was the most important driver of business-cycle fluctuations in recent years (Sanjani, 2014; Liu et al., 2011; Justiniano et al., 2011). In the light of these findings, my results suggest that including capital quality shocks into the research agenda of the international business-cycle literature might constitute an important step forward in explaining the global scope of the recent economic crisis.

Similar theoretical accounts of the risks resulting from balance sheet exposure so far have only considered technology shocks and shocks to the net worth of investors. They do not feature a banking sector. Using a two-country New Keynesian model with leverage-constrained investors, Dedola and Lombardo (2012, p. 319) argue that price equalization in integrated financial markets leads to business-cycle comovement "quite independently of the exposure to foreign assets in the balance sheet of leveraged investors". Their model features perfect deposit market integration which leads to an equalization of credit spreads, while in my model deposit rates are only partly equalized due to the presence of a debt-elastic interest rate yield.[1] A similar contribution is the model by Yao (2012) which features non-separable preferences. She comes to the conclusion that a higher degree of balance sheet exposure leads to higher international business-cycle comovement in the case of technology shocks. However, varying the degree of balance sheets exposure only has quantitative effects. Dedola et al. (2013) and Carniti (2012) have proposed two-country frameworks with banks and integrated financial markets, very similar to the one in the present paper. They also analyze the effects of capital quality shocks under different degrees of balance sheet exposure, however, they are mainly interested in the question how unconventional monetary policy should be conducted in this context.

While much evidence has been brought forward that the balance sheet channel has played an important role in the financial crises of the nineties (see, e.g., Kaminsky and Reinhart, 2000), empirical evidence with respect to the direct role of foreign asset holdings during the 'Great Recession' is mixed. For instance, using a cross-country dataset, Rose and Spiegel (2010) come to the conclusion that exposure to U.S. assets cannot account for the observed cross-country differences in decline in output growth. On the other hand, using a similar methodology but additionally including data on consumption and total domestic demand to measure recessions, Lane and Milesi-Ferretti (2010) find that exposure to foreign assets worked as an important channel of transmission during the recent crisis.

The paper is organized as follows. The next section develops the model. Section 2.3 provides the calibration. In section 2.5, I present and discuss the results. The final section concludes and gives an outlook.

2.2 Model

The setup of the model closely follows Dedola et al. (2013), except for the modeling of international intermediaries (subsection 2.2.2). It is assumed that the world consists of two countries with symmetric structures, each inhabited by a continuum of agents of equal size.

[1] In section 2.5.3, I show that the degree of foreign exposure still plays an important role for the cross-country transmission of capital quality shocks, even if I consider a version of the model which features highly correlated credit spreads.

Each country features a financial intermediation sector. The role of intermediaries is to transfer funds between households and final goods producers who use the loans to finance investment into physical capital. Intermediaries face an endogenously determined constraint on their leverage ratio, motivated by a simple agency problem which drives a wedge between saving and borrowing rates.

The two-country version of the model developed here features final goods market integration as well as asset and deposit market integration. To allow for these multiple interlinkages, I have to abstract from complete international consumption risk sharing. Allowing the net foreign asset position to be adjusted via two margins - equity and bond trade - might imply two unit roots in a first-order approximation of the model (see, e.g., Schmitt-Grohé and Uribe, 2003). Hence, I introduce two stationarity-inducing features, an endogenous discount factor, which dates back to Uzawa (1968), and a debt-elastic interest rate yield.

Integration of asset markets is modeled by assuming that intermediaries can purchase financial claims on final goods producing firms at home and abroad as in Dedola et al. (2013) and Carniti (2012). This introduces an endogenous portfolio choice problem as returns to equity are subject to country-specific risk. I solve this problem using the method proposed by Devereux and Sutherland (2007; 2008; 2011a) (see section 2.4).

For simplicity only home country equations will be displayed. Foreign variables will be denoted with an asterisk.

2.2.1 Households

Within each household, there are two member types, workers and bankers. While the worker supplies work to final goods firms and deposits to banks, the banker manages a financial intermediary and transfers retained earnings back to her household when the lifetime of the bank ends. Within the family, there is perfect consumption risk sharing, which allows to maintain the representative agent framework. As in Gertler and Karadi (2011), it is assumed that a fraction $1 - f$ of household members are depositors, while a fraction f are bankers. Between periods there is a random turnover between the two groups: with probability θ_b a banker will stay a banker and with probability $1 - \theta_b$ she will become a depositor. The relative proportions are kept fixed. New bankers are provided with some start-up funds from their respective households.

The lifetime utility of a representative home worker, who draws utility from consumption C_t and disutility from labor L_t, is given by

$$E_t \sum_{k=0}^{\infty} \Theta_{t+k} \left(\ln C_{t+k} - \chi \frac{L_{t+k}^{1+\phi}}{1+\phi} \right),$$

where ϕ is the inverse of the Frisch elasticity of labor supply and χ determines the weight of disutility of labor in the utility function. Variable Θ_t represents the endogenous discount factor of households chosen to ensure stationarity as explained below.

Households save by depositing funds at domestic and foreign banks (see 2.2.2 for details). Total deposits held between $t-1$ and t, denoted by D_{t-1}, are equivalent to one-period riskless real bonds paying the gross real rate of return R_{t-1}. Furthermore, households provide labor to final goods firms and receive the real wage w_t. Hence, the home household's budget constraint is given by

$$C_t + D_t = R_{t-1}D_{t-1} + w_t L_t + \Upsilon_t,$$

where Υ_t denotes net profits from the ownership of firms (financial and non-financial).

The endogenous discount factor is determined as follows

$$\begin{aligned} \Theta_{t+1} &= \Theta_t \beta(C_{A,t}), \\ \Theta_0 &= 1, \end{aligned}$$

where $C_{A,t}$ is aggregate home consumption. Using aggregate consumption in the endogenous discount factor ensures that the household does not internalize the effect of her consumption decision on the discount factor, which simplifies calculations considerably (cf. Schmitt-Grohé and Uribe, 2003). As in Schmitt-Grohé and Uribe (2003) and Devereux and Yetman (2010) the following functional form of the endogenous discount factor is assumed

$$\beta(C_{A,t}) = \omega_c(1 + C_{A,t})^{-\eta_c}. \tag{2.1}$$

Parameter η_c drives the elasticity of the discount factor with respect to consumption. Parameter ω_c captures the steady-state savings propensity. Note that the discount factor decreases in $C_{A,t}$, i.e., whenever a country has relatively higher consumption in the present, it discounts future consumption more heavily and, hence, saves less. The latter implies lower consumption in the future and, therefore, the economy returns to the initial state.

Hence, the household's first-order conditions for the optimal choice of labor and consumption are given by

$$w_t = \chi \frac{L_t^{\phi}}{\lambda_t}, \tag{2.2}$$

and

$$1 = \beta(C_{A,t}) E_t \Lambda_{t,t+1} R_t, \tag{2.3}$$

with the household's real stochastic discount factor defined as

$$\Lambda_{t,t+1} \equiv \frac{\lambda_{t+1}}{\lambda_t}, \tag{2.4}$$

where λ_t denotes the marginal utility of consumption given by

$$\lambda_t = C_t^{-1}. \tag{2.5}$$

2.2.2 International Intermediaries

To simplify matters, I implicitly assume that households hold their deposits with savings banks which – according to the needs in the financial system – channel the funds to home and foreign banks via international intermediaries. Total deposits of home households are given by $D_t = D_{H,t} + D_{F,t}$.

Allowing deposits to freely flow between countries, would induce a unit root. Therefore, it is assumed that home deposits can only be channeled to foreign banks by purchasing one-period bonds from international intermediaries. The latter charge a small interest-rate premium on the real interest rate, hence, home and foreign deposits rates are only imperfectly correlated. The premium depends on the real net foreign bond position of the respective country (see, e.g., Hjortsoe, 2016) This assumption adds realism to the model and ensures stationarity (see, e.g., Schmitt-Grohé and Uribe, 2003). As in Hjortsoe (2016), I assume

$$R_t = R_t^* \Phi(D_{F,t}), \tag{2.6}$$

where R_t^* is the foreign real riskless rate of return. It is assumed that the country-specific rate charged by international intermediaries is increasing in the deviation of the external household debt position (real debt is given by $-D_{F,t}$) from its steady state, i.e., $\Phi(\cdot)' < 0$ and $\Phi(0) = 0$. As in Hjortsoe (2016), the following functional form is chosen for the debt-elastic interest-rate premium

$$\Phi(D_{F,t}) = (1 - \omega_d D_{F,t}).$$

Parameter ω_d is the yield sensitivity of debt.

Profits of international intermediaries are equally split between households in the two countries. Note that rates of return on home deposits and bonds (equivalent to deposit holdings with foreign banks, $D_{F,t}$) are equalized due to arbitrage.

2.2.3 Banks

The setup of the banking sector closely follows Dedola et al. (2013). Home financial intermediaries channel funds from home and foreign households to home and foreign final goods producers, fulfilling the double role of investment as well as commercial banks. In addition to obtaining funds from households, banks also raise funds internally by accumulating retained earnings. The balance sheet of home bank i is given by

$$Q_t S_{iH,t} + Q_t^* S_{iF,t} = D_{i,t}^B + N_{i,t}, \tag{2.7}$$

where Q_t (Q_t^*) denotes the price of the home (foreign) capital asset. Deposits at bank i, stemming from home and foreign households, are denoted by $D_{i,t}^B = D_{iH,t} + D_{iH,t}^*$. Variable $S_{iH,t}$ ($S_{iF,t}$) denotes state-contingent claims on future returns of a unit of capital used in final goods production in the home (foreign) country one period later, whose gross rate of return is given by $R_{k,t}$ ($R_{k,t}^*$). Intermediary i's net worth is given by $N_{i,t}$. It evolves according to the following equation

$$N_{it} = R_{k,t} Q_{t-1} S_{iH,t-1} + R_{k,t}^* Q_{t-1}^* S_{iF,t-1} - R_{t-1} D_{i,t-1}^B.$$

As can be seen from the equation above, any growth in banks' equity capital above the riskless rate depends on the premia $R_{k,t} - R_{t-1}$ and $R_{k,t}^* - R_{t-1}$ and on the quantity of assets. Financial intermediaries cannot fund assets with an expected discounted premium below zero. In a frictionless financial market, risk-adjusted premia would always be zero. In my model, due to the presence of a leverage constraint, the spread is positive. As will be seen later, it covaries negatively with GDP, as banks' inability to obtain funds increases during bad states of the economy.

As it is assumed that each period a fraction 1-θ_b of bankers exits the business with i.i.d. probability and pays out accumulated earnings to their respective households,[2] a banker maximizes the terminal value of her net worth given by

$$V_t = \max\ E_t \sum_{k=0}^{\infty} (1-\theta_b)\theta_b^k \Theta_{t+k} \Lambda_{t,t+k+1} N_{i,t+k+1}.$$

To motivate the requirement to build up net worth, the following moral hazard problem is assumed: At the beginning of each period, before the shocks realize and any other transactions take place, the banker can choose to divert the fraction λ_b of available funds back to the household. The cost associated with this fraud is that the depositors recover the remaining fraction $1 - \lambda_b$ and force the banker into bankruptcy. Therefore, for households to be willing to deposit funds with the bank, the following incentive constraint must hold

$$V_{i,t} \geq \lambda_b B_{i,t}, \tag{2.8}$$

[2]This arrangement precludes bankers from aggregating so much net worth that the incentive constraint becomes irrelevant for them.

with $B_{i,t} \equiv Q_t S_{iH,t} + Q_t^* S_{iF,t}$ denoting total bank assets. To solve the banker's maximization problem define the objective of the bank recursively as

$$V_{i,t} = \max\ E_t \beta(C_{A,t})\Lambda_{t,t+1}[(1-\theta_b)N_{i,t+1} + \theta_b V_{i,t+1}],$$

and conjecture that the value function is linear in assets and net worth,

$$V_{i,t} = \nu_{iH,t} Q_t S_{iH,t} + \nu_{iF,t} Q_t^* S_{iF,t} + \eta_{i,t} N_{i,t}.$$

The banker's problem consists in choosing the amount of home assets, $S_{iH,t}$, foreign assets, $S_{iF,t}$ and deposits $D_{i,t}^B$ such that terminal net worth is maximized and the incentive constraint holds. It can be solved using the Lagrange method.[3]

The solutions for the coefficients are given by

$$\nu_{H,t} = E_t \Omega_{t,t+1}(R_{k,t+1} - R_t) \tag{2.9}$$

$$\nu_{F,t} = E_t \Omega_{t,t+1}(R_{k,t+1}^* - R_t) \tag{2.10}$$

$$\eta_t = E_t \Omega_{t,t+1} R_t, \tag{2.11}$$

where

$$\Omega_{t,t+1} = \beta(C_{A,t})\Lambda_{t,t+1}\left[(1-\theta_b) + \theta_b\left(\eta_{t+1} + \nu_{t+1}\phi_{t+1}\right)\right], \tag{2.12}$$

where $\phi_t \equiv \frac{\eta_t}{\lambda_b - \nu_t}$ is the leverage ratio (see below). Variable $\Omega_{t,t+1}$ can be interpreted as the stochastic discount factor of the banker. It differs from the household's stochastic discount factor due to the presence of financial frictions. The discount factor is a key variable for the determination of international portfolio positions. The difference between the two agents' discount factors drives one of the results of this paper: The fact that in this model the portfolio decision is made by the banker instead of the household leads to inefficiently low insurance of country-specific consumption risk (cf. section 2.5.1). The reason is that bankers have a motive in addition to the maximization of lifetime utility, namely, the maximization of terminal net wealth. Note that the subscript i was dropped as the coefficients exclusively depend on aggregate variables.

A further first-order condition is given by

$$\nu_{H,t} = \nu_{F,t} \equiv \nu_t \ \Leftrightarrow\ E_t \Omega_{t,t+1} R_{k,t+1} = E_t \Omega_{t,t+1} R_{k,t+1}^*. \tag{2.13}$$

It is the first-order condition relevant for optimal portfolio choice as will be explained further in section 2.4.

[3] Detailed derivations can be found in the appendix (section A.1).

Assuming that the incentive constraint binds,[4] it can be expressed in terms of the coefficients of the value function

$$B_t = \frac{\eta_t}{\lambda_b - \nu_t} N_t = \phi_t N_t, \tag{2.14}$$

where ϕ_t is the ratio of intermediated assets to net worth, which can be referred to as the leverage ratio. Note that it is determined endogenously in this model.

Finally, the law of motion for aggregate net worth can be derived as

$$N_t = N_{n,t} + N_{e,t}\, \Xi_{N,t} \tag{2.15}$$

$$N_{e,t} = \theta_b \left[\left((R_{k,t} - R_{t-1}) - \frac{Q^*_{t-1} S_{F,t-1}}{B_{t-1}} (R_{k,t} - R^*_{k,t}) \right) \phi_{t-1} + R_{t-1} \right] N_{t-1} \tag{2.16}$$

$$N_{n,t} = \omega_b [Q_{t-1} S_{H,t-1} + Q^*_{t-1} S_{F,t-1}], \tag{2.17}$$

where $N_{e,t}$ denotes existing bankers' net worth, $N_{n,t}$ denotes new bankers' net worth and ω_b is the fraction of the assets given to new bankers by their households. Variable $\Xi_{N,t}$ denotes an exogenous disturbance to the net worth of existing bankers.

2.2.4 Final Goods Firms

Final goods producing firms can sell their products to home and foreign consumers in a perfectly competitive market.

The Cobb-Douglas production function of the representative final goods firm is given by

$$Y_t \;=\; A_t (\Psi_t K_{t-1})^{\alpha} L_t^{1-\alpha}, \tag{2.18}$$

where Y_t denotes output, A_t technology and Ψ_t capital quality. Parameter α denotes the output elasticity of capital. Labor L_t is provided by households in the same country only. Capital K_{t-1} was bought from capital goods producers in the same country in the previous period at price Q_{t-1}. To obtain funds to finance capital purchases, the firm issues state-contingent securities to home and foreign intermediaries at the same price. Each period, after being productive, the firm has to pay back capital returns on the securities issued in the previous period. As in Gertler and Karadi (2011) I assume a shock to the quality of capital to provide a source for exogenous variations in the price of capital. It can be interpreted as the sudden realization that much of the capital installed is of lower quality than previously thought. As capital provides collateral to banks, banks' balance sheets will be contracted in response to a negative capital quality shock. The law of motion

[4] Parameters and steady-state values are chosen such that the incentive constraint binds in the steady state. Holding shocks small enough guarantees that the incentive constraint also binds in a stochastic environment.

for capital is given by

$$K_t = I_t + (1-\delta)\Psi_t K_{t-1}, \tag{2.19}$$

where I_t is aggregate investment and δ denotes physical depreciation.

The first-order conditions of the final goods producer's profit maximization problem are, therefore, given by

$$R_{k,t+1} = \frac{\alpha \frac{Y_{t+1}}{K_t} + (1-\delta)\Psi_{t+1} Q_{t+1}}{Q_t}, \tag{2.20}$$

and

$$w_t = (1-\alpha)\frac{Y_t}{L_t}. \tag{2.21}$$

The firm earns zero profits state-by-state, hence, it simply pays out the ex post return to capital, $R_{k,t}$, to the financial intermediary.

2.2.5 Capital Goods Firms

Competitive capital goods firms produce capital only for the domestic market using national final output as input facing investment adjustment costs (in consumption units). Adjustment costs are assumed to be proportional to the aggregate past capital stock as in Dedola et al. (2013).[5] Their functional form is given by

$$f(\cdot) = \frac{\eta_I}{2}\left(\frac{I_t}{\delta K_{t-1}} - 1\right)^2 \frac{\delta K_{t-1}}{I_t}, \tag{2.22}$$

with $\eta_I > 0$, denoting the inverse elasticity of investment with respect to price of capital. The capital goods producer chooses I_t to maximize lifetime profits given by

$$E_t \sum_{k=0}^{\infty} \Theta_{t+k} \Lambda_{t,t+k} \left\{ Q_{t+k} I_{t+k} - \left[1 + f(\cdot)\right] I_{t+k} \right\}.$$

From the first order conditions, I obtain the real price of one unit of capital

$$Q_t = 1 + \eta_I \left(\frac{I_t}{\delta K_{t-1}} - 1\right). \tag{2.23}$$

Due to flow investment costs, capital goods firms can earn profits outside the steady state. These profits are distributed lump-sum to the households.

[5] Using adjustment costs proportional to the change in investment, instead, results in excessive volatility of investment and – implied by this – excessive volatility of other real variables such as output. This was also pointed out by Dmitriev and Roberts (2013), however, for two-country models with perfect risk-sharing.

2.2.6 Market Clearing and Aggregate Resource Constraint

The capital market clearing condition states that in each country, the current value of total installed capital has to be equal to the total value of state-contingent claims on future returns of capital

$$Q_t K_t = Q_t(S_{H,t} + S^*_{H,t}). \tag{2.24}$$

International final goods market clearing is given by

$$Y_t + Y^*_t = C_t + C^*_t + [1 + f(\cdot)]I_t + [1 + f^*(\cdot)]I^*_t. \tag{2.25}$$

The home aggregate resource constraint is derived from the aggregation of the budget constraint over home households, considering profits from the ownership of non-financial firms, retained earnings from exiting bankers and transfers to new bankers

$$\begin{aligned} Y_t + Q^*_{t-1} S_{F,t-1} R^*_{k,t-1} - Q_{t-1} S^*_{H,t-1} R_{k,t-1} + D_{F,t-1} R_{t-1} + 0.5\Upsilon^{\mathrm{IFI}}_t \\ = C_t + [1 + f(\cdot)]I_t + Q^*_t S_{F,t} - Q_t S^*_{H,t} + D_{F,t}, \end{aligned} \tag{2.26}$$

where $\Upsilon^{\mathrm{IFI}}_t = (R^*_t - R_t)D_{F,t}$ are profits from international financial intermediaries which are equally split between countries.

Bonds are in zero net supply, i.e.,

$$D_{F,t} = -D^*_{H,t},$$

where $D^*_{H,t}$ denotes foreign households' deposits in home banks or, more specifically, foreign international bond holdings invested in home banks.

The equilibrium conditions of the full model are collected in the appendix (section A.2.1).

2.3 Calibration

Table 3.1 reports the baseline calibration and its sources. The time unit is one quarter. Most parameters are quite standard and do not need to be discussed.

The weight of labor in the utility function was chosen to ensure that a household devotes one third of her time to work.

The parameters of the banking system, λ_b, the divertable fraction of assets, θ_b, the average lifetime of banks, and ω_b, the transfer to entering bankers, are taken from Gertler and Karadi (2011). They choose these values to hit three targets: a steady-state interest rate spread of 100 basis points, a steady-state leverage ratio of four and an average lifetime of a bank of 10 years.

Parameter	Description	Value	Source
Households			
ϕ	inverse of Frisch elasticity	0.276	Gertler and Karadi (2011)
χ	utility weight of labor	3.492	
η_c	parameter from discount factor	0.010	Devereux and Sutherland (2009)
ω_c	parameter capturing steady-state savings propensity	0.996	
ω_d	yield sensitivity to debt	0.010	Hjortsoe (2016)
Capital goods firms			
η_I	inverse elasticity of investment with respect to price of capital	1.728	Gertler and Karadi (2011)
Final goods firms			
α	output elasticity of capital	0.330	Gertler and Karadi (2011)
δ	depreciation rate	0.025	Gertler and Karadi (2011)
Financial intermediaries			
λ_b	fraction of divertable assets	0.381	Gertler and Karadi (2011)
ω_b	transfer to entering banks	0.002	Gertler and Karadi (2011)
θ_b	quarterly survival rate of banks	0.972	Gertler and Karadi (2011)
Exogenous processes			
ρ_ψ	persistence of capital quality shock	0.66	Gertler and Karadi (2011)
ρ_A	persistence of technology shock	0.95	Gertler and Karadi (2011)
ρ_N	persistence of net wealth shock	0.66	
σ_ψ, σ_A, σ_N	standard deviation of shocks	0.01	

Table 2.1: *Parameters*

Parameter η_c in the endogenous discount factor was taken from Devereux and Sutherland (2009). In general, it should be noted that this parameter can have considerable implications for the international transmission of shocks. Hence, it should be set to a small value. However, choosing it to be too small induces a unit root in a first-order approximation of the model. The same is true for ω_d, the yield sensitivity to debt, which is calibrated as in Hjortsoe (2016).[6] Given $\eta_c = 0.01$ and the steady-state value of consumption, parameter ω_c was chosen as to guarantee an annual steady-state interest rate of 4%, i.e., a steady-state value of $\beta(C_A)$ of 0.99.

The three exogenous variables A_t, Ψ_t and $\Xi_{N,t}$ are assumed to follow AR(1) processes. Persistency and standard deviation of the technology shock are taken from Gertler and Karadi (2011). The persistency of the net wealth shock is set to 0.66 which is equal to the persistency of the capital quality shock. The reason is that the capital quality shock, as well as the net wealth shock directly affect stock

[6]In section 2.5.3, I discuss the robustness of the results with respect to choosing a lower value of ω_d, i.e., a higher degree of deposit market integration.

variables and, hence, feature a high endogenous persistency. The size of the capital quality shock is set equal to the standard deviation of the other shocks.

2.4 Portfolio Indeterminacy and Solution Method

Recall home banks' first-order condition $\nu_{H,t} = \nu_{F,t}$ which can be rewritten as

$$E_t \Omega_{t,t+1} R_{k,t+1} = E_t \Omega_{t,t+1} R^*_{kt+1}.$$

Evaluated in the non-stochastic steady state, this equation becomes

$$R_k = R^*_k,$$

and, approximated up to first order,

$$E_t R_{k,t+1} \approx E_t R^*_{k,t+1}.$$

Hence, in the steady state and evaluated up to first-order, both assets pay the same return. This implies that all possible compositions of banks' portfolios, given by $B_t = Q_t S_{H,t} + Q^*_t S_{F,t}$, pay the same return in the non-stochastic steady state and in expectations, evaluated up to a first order. Therefore, international portfolio choice is indeterminate up to first-order accuracy. The economic intuition behind this indeterminacy problem is that the two capital assets are only distinguishable in terms of their risk characteristics which can only be captured with an approximation of second-order or higher (Devereux and Sutherland, 2008).

It can be shown that only steady-state portfolio shares matter for the (first-order) dynamics of the remaining variables. To find the steady-state portfolio shares, I use the method proposed by Devereux and Sutherland (2007; 2008; 2011a). It is based on a second-order approximation of the portfolio equations and a first-order approximation of the non-portfolio parts of the model. Recently, other local and global methods have been proposed by other authors,[7] however, the method developed by Devereux and Sutherland is particularly appealing as it uses well-known perturbation techniques and can be quite easily incorporated into otherwise standard programs used to solve DSGE models, e.g., Dynare. In chapter 4, I provide a more detailed description of this solution method.

[7]The methods proposed by Tille and van Wincoop (2010) and Evans and Hnatkovska (2005) also employ perturbation around a non-stochastic steady state to find international portfolios while Coeurdacier et al. (2011) and Juillard (2011) propose to find international portfolios by approximating DSGE models around the risky steady state. Brunnermeier and Sannikov (2015) are able to solve a model featuring an international portfolio choice problem globally by using continuous time.

2.5 Results

In this section, I first present and briefly discuss the optimal steady-state portfolio share obtained with the Devereux and Sutherland (2007; 2008; 2011a) method. In subsection 2.5.2, the main transmission mechanisms of the model are discussed. To this purpose, I compare the impulse responses of an environment in which the portfolio is optimally chosen by banks to those prevailing in an environment with an arbitrary foreign asset share of 0 and to those which result from an environment of financial market autarky. In the last subsection, I briefly discuss the robustness of the results with respect to varying certain model features.

2.5.1 Steady-State Portfolio Holdings

Steady state portfolio holdings in this model are defined as

$$\gamma \equiv \frac{Q^* S_f}{Q^* S_f + Q S_h} = \frac{Q S_h^*}{Q^* S_f^* + Q S_h^*},$$

i.e., the share of foreign capital holdings in home banks' portfolios, which – due to symmetry – is equal to the share of home capital holdings in foreign banks' portfolios.

Using the benchmark calibration, steady-state foreign portfolio holdings amount to 0.64, i.e., financial intermediaries hold portfolios with a foreign bias. This result is fairly robust to varying parameter values. Data on international portfolio holdings show that developed countries exhibit an equity home bias of 60-80%, i.e., a γ between 0.2 and 0.4 (see, e.g., Coeurdacier and Rey, 2012). The model at hand cannot replicate this characteristic of international financial markets – a weakness shared by many other two-country models with endogenous portfolio choice. There are also various contributions proposing certain model features which lead to home bias in international portfolios. Coeurdacier and Rey (2012) provide an excellent review of this literature. As the focus of the present paper is different, I refrain from extending the model in a way that it matches data on international portfolio holdings more closely.

In models with international portfolio choice, agents choose portfolio holdings as to optimally insure against country-specific risks. In most of the literature on international portfolio choice, households undertake the portfolio choice decision. Their objective is to choose the portfolio which ensures the best hedging of country-specific consumption risk. A feature of my model is that bankers undertake portfolio decisions instead of households[8] which is a justified assumption given that in

[8] The models by Dedola et al. (2013) and Carniti (2012) feature the same setup of the banking system as my model, however, they do not analyze the implications of portfolio choice by bankers in detail. In Dedola and Lombardo (2012), Yao (2012) and Devereux and Yetman (2010) so-called

the real world a large part of international portfolio holdings is managed by financial intermediaries (Coeurdacier and Rey, 2012). This assumption, however, has important implications for international portfolio choice and consumption risk-sharing. Measuring the latter as the correlation between home and foreign marginal utilities (see, e.g., Nuntramas, 2011), it can be shown, that the foreign asset share chosen by bankers is, generally, lower than a foreign asset share which maximizes international consumption risk-sharing. This is an interesting feature of the model. In fact, it might help reconcile theory with empirical evidence on relatively low foreign asset holdings and modest degrees of international consumption risk sharing despite open financial markets (see, e.g., Kose et al., 2009). Therefore, I will further analyze the implications of international portfolio choice by banks for international equity positions and consumption risk-sharing in chapter 4.

2.5.2 Impulse Response Analyses

In this section, I analyze the impulse responses to an adverse home capital quality shock and compare them to the impulse responses to shocks which have been considered in previous analyses of the role of balance sheet exposure for the international transmission of shocks, in particular technology shocks and net worth shocks. The aim of the present paper is not to perfectly capture realistic dynamics, but to analyze the role of the financial sector for the global comovement observed in recent years. Hence, I will focus on a discussion of the responses of GDP as the main indicator of real economic activity and of those financial variables which illustrate the international transmission well.

Home banks		*Foreign banks*	
assets	liabilities	assets	liabilities
$Q_t S_{H,t}$	N_t	$Q_t S^*_{H,t}$	N^*_t
$Q^*_t S_{F,t}$	D^B_t	$Q^*_t S^*_{F,t}$	D^{B*}_t

Figure 2.1: *Banks' Balance Sheets under Financial Market Integration*

I begin by explaining the international transmission of the shocks via the financial sector along the balance sheets of home and foreign banks under financial market integration (figure 2.1). Suppose a negative technology shock hits the production function of the home economy. As a direct effect, the return to home capital and home investment demand are reduced. This exerts downward pressure

'investors' undertake the portfolio decision, but their objective is also the maximization of lifetime utility, i.e., the stochastic discount factor relevant for international portfolio choice is equivalent to the households' one.

on the price of home capital, Q_t and thereby affects banks' balance sheets negatively. Hence, this shock transmits from the real to the financial sector primarily via prices. Under financial market integration, capital prices are nearly equalized due to the equalization of expected returns. Therefore, this shock also reaches foreign banks balance sheets mainly via asset price equalization. Now, suppose that a net wealth shock hits home banks' balance sheets, i.e., N_t drops exogenously. The home bank has to deleverage to meet balance sheet constraints. This fire sale of assets exerts downward pressure on asset prices, thereby affecting the asset side of banks' balance sheets. As before, foreign banks balance sheets are mainly affected via price equalization. When a capital quality shock hits the home economy, the same price equalization channel as for the previous two shocks comes into effect. However, there is an additional effect on the financial sector. Recall that the capital quality shock not only hits the production function, but also destroys part of the capital stock. As the capital stock is equal to the capital claims issued to banks, the decline in home capital quality causes a devaluation of home capital assets, i.e., of $S_{H,t}$ and $S^*_{H,t}$. The foreign bank suffers from this decline in asset values proportionately to its home asset holdings.

I now turn to the impulse response analysis. I assume three environments in which the shocks hit the home economy: 1) financial market autarky, i.e., neither deposit nor capital market integration,[9] 2) financial market integration, i.e., deposit and capital market integration, and full home bias, i.e., $\gamma = 0$, and 3) financial market integration, i.e., deposit and capital market integration, and an optimal portfolio, i.e., $\gamma = 0.64$. The second setting can be seen as a rather hypothetical case in which banks are allowed to trade financial assets – therefore, asset returns are equalized in expectations – however, actual international asset holdings are set to zero. This setting allows me to single out the price equalization channel, as the balance sheet exposure channel is turned off by construction.

Capital quality shocks

Figure 2.2 shows the impulse responses to a capital quality shock in the home country. The solid blue line and the dashed black line display the impulse responses under financial market integration. The solid blue line gives the impulse responses under full home bias and the dashed black line depicts the impulse responses under optimal diversification.

[9]In the present model, in which both countries produce the same good, financial market autarky implies trade autarky.

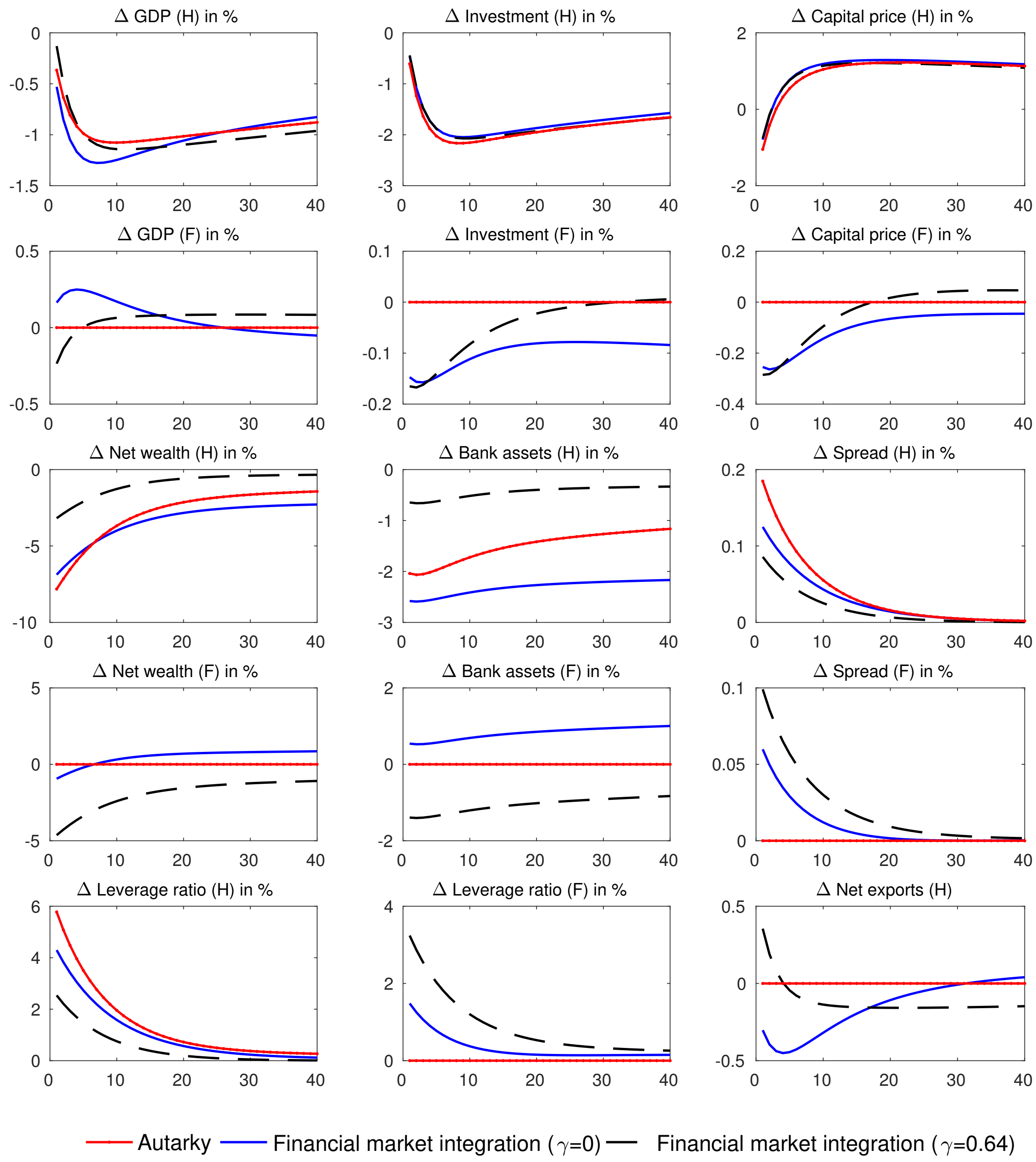

Figure 2.2: *Impulse Responses to an Adverse 1% Home Capital Quality Shock*

The size of the effects on the foreign banking system depends very much on the share of home assets in foreign banks' portfolios, γ. Foreign banks' net worth is only affected very little under the assumption of full home bias and the foreign spread (defined as the difference between the expected return to capital and the foreign deposit rate) even decreases. The effects on the real economy also differ largely. Under full home bias ($\gamma = 0$), the adverse shock in the home country actually triggers a small boom in the foreign economy, while under optimal diversification ($\gamma = 0.64$) the recession is synchronized in the short run. The reason for the different transmission of the same shock is that under optimal diversification, foreign banks are affected through a direct devaluation of some of their assets, in particular through a direct devaluation of $S^*_{H,t}$, and through asset price equalization while under full home bias only the latter channel plays a role. The price equalization channel works through an equalization of expected returns on capital due to arbitrage. The equalization of expected returns pushes capital demand and, hence, capital prices into the same direction during the initial periods following the shock. Price equalization attenuates the effects of the shock in the home economy while it is a channel of financial contagion for the foreign economy. If only the price equalization effect is at work, which is the case for $\gamma = 0$, the foreign economy initially even profits from the shock in the home country. The reason is that it can increase exports to the home economy where demand did not drop as much as under financial autarky because there the financial accelerator was attenuated. If banks hold diversified portfolios, i.e., $\gamma = 0.64$, foreign banks are directly affected by the home shock to a similar extent as home banks. This activates a powerful balance sheet mechanism in the foreign economy: as can be seen in figure 2.2, foreign banks' net worth drops by a similar amount as in the home economy. Due to the leverage ratio constraint, foreign banks have to further reduce their asset holdings.

The result that home and foreign output are negatively correlated under full home bias but positively correlated under a diversified portfolio is robust to variations of the trade sector of the model. In particular, a version of the model with trade in imperfectly substitutable home and foreign goods and potentially sticky prices yields qualitatively the same results.

Other shocks

The impulse responses to the net worth shock and the technology shock can be found in the appendix. As before, the solid blue line gives the impulse responses under full home bias ($\gamma = 0$) and the dashed black line depicts the impulse responses under optimal diversification ($\gamma = 0.64$). The effects of the technology shock on the home economy are similar to those of the capital quality shock. The initial responses are more pronounced and the impulse responses do not display a hump shape as there is only the direct effect on the production function which is, however, larger than for a capital quality shock of the same size. The effects of the net worth shock – a purely financial shock – on the real economy are quite small which has already been observed by Dedola et al. (2013).

With respect to the role of γ for the international transmission of these shocks, it can be seen that the degree of exposure matters much less and only quantitatively in the case of technology shocks and almost not at all in the case of net worth shocks. As explained above, the reason is that in response to these shocks, financial contagion arises mainly through asset price equalization. In this regard, my results resemble those of previous accounts of the role of balance sheet exposure for the international transmission of shocks (cf. Dedola and Lombardo, 2012; Yao, 2012).

However, my results deviate from those of Dedola and Lombardo (2012) and Yao (2012) in that the correlation of home and foreign GDP for technology and net worth shocks is negative in my model. As their models differ from mine in various respects, I cannot conclusively say which features are responsible for the different cross-country correlations. However, when running some robustness checks, I found that the international comovement of output conditional on technology shocks depends very much on the modeling of the trade sector. For example, introducing a more sophisticated international trade sector with home and foreign goods and sticky prices as in Dedola and Lombardo (2012) into my model yields a positive correlation of output across countries, if the trade elasticity is low enough.

To sum up, whether balance sheet exposure matters for international contagion depends on the type of shock. The reason is that technology and net worth shocks are mainly transmitted via an equalization of asset prices, whereas capital quality shocks are additionally transmitted through direct valuation effects. My results imply that an evaluation of the risks of balance sheet exposure must go beyond an analysis of unconditional cross-country correlations. Instead, we need to find out which shocks are the most important drivers of international business cycles.

2.5.3 Robustness Checks

In this section, I assess the sensitivity of my results with respect to altering certain model features in a way that my model more closely resembles the setup used in related literature, e.g., Dedola and Lombardo (2012).

Degree of Deposit Market Integration

In Dedola and Lombardo (2012) and Dedola et al. (2013) international bond markets are perfectly integrated which implies perfect equalization of credit spreads in a first-order approximation of the model. This might have implications for cross-country correlations and the role of balance sheet exposure therein. The reason for this is that the equalization of spreads also implies a high synchronization of leverage ratios, even if balance sheet exposure is low. In the given setup, however, allowing bonds to freely flow between countries implies a unit root in a first-order approximation of the model. Therefore, I refrain from allowing frictionless trade in bonds. Nevertheless, in my model, a higher synchronization of spreads can be achieved by decreasing the friction in international deposit markets, i.e., by choosing a lower value of ω_d.

Figure A.3 in the appendix shows the impulse responses to a negative home capital quality shock for $\omega_d = 0.001$. Given the higher degree of deposit market integration, the initial response of foreign GDP in the scenario with financial market integration and full home bias ($\gamma = 0$) is altered. Now, initially, foreign GDP also slightly drops in response to an adverse home capital quality shock. Furthermore, the responses of the spreads and leverage ratios differ much less between the scenarios of full home bias ($\gamma = 0$) and optimal portfolio diversification ($\gamma = 0.71$). Nevertheless, although the price equalization channel becomes more important when deposit market integration is higher, it still holds that balance sheet exposure matters significantly for international comovement in the presence of capital quality shocks, while it plays a much smaller role when, e.g., technology shocks drive the business cycle.

Sticky Prices

As sticky prices are known to affect the risk sharing properties of assets (Engel and Matsumoto, 2009) and to ensure better comparability to the analysis by Dedola and Lombardo (2012), I also analyze a version of my model with trade in home and foreign goods and sticky prices. Section A.4.2 of the appendix contains a brief summary of this model version and the corresponding impulse response figures.

The main results regarding the cross-country transmission of capital quality shocks, technology shocks and net wealth shocks under different degrees of balance sheet exposure remain – by and large – unchanged: Balance sheet exposure is essential for global comovement in the case of capital quality shocks but plays a much smaller role for cross-country correlations conditional on technology shocks and net wealth shocks. A difference to the original model is that, in response to an adverse home technology shock, foreign GDP drops below its steady state value for approximately one period if balance sheet exposure is high, while it increases directly under the assumption of $\gamma = 0$. Furthermore, I find that the cross-country correlation of GDP conditional on technology shocks changes its sign depending on the elasticity of substitution between home and foreign goods (ι). For a reasonable value of $\iota = 1.5$, the model exhibits a strong negative initial response of foreign GDP to a negative home country technology shock under all three setups of the financial market.

2.6 Conclusion

By estimating closed economy DSGE models, various authors have recently shown that capital quality shocks are the “key drivers of business-cycle fluctuations” (Justiniano et al., 2011; Liu et al., 2011; Sanjani, 2014, p. 23). In an open economy context, – in empirical as well as theoretical studies – these shocks have been given little attention, so far. Considering technology and net worth shocks, previous theoretical accounts of the role of balance sheet exposure for the international transmission of shocks came to the conclusion that the share of foreign assets in investors' portfolios matters at most quantitatively for the synchronization of business cycles (Dedola and Lombardo, 2012; Yao, 2012). My model extends existing research by studying the international transmission of capital quality shocks and the role of balance sheet exposure of leveraged financial intermediaries therein. I show that conditional on capital quality shocks, balance sheet exposure has an important impact on international business-cycle synchronization. In fact, moving from a setting with negligibly low foreign portfolio holdings to a model with completely diversified portfolios changes the sign of the correlation of home and foreign output from negative to positive. This is an important finding as it suggests that an evaluation of the potential risks of cross-country asset holdings must go beyond an analysis of unconditional cross-country correlations. To gain more insights into the question which role price equalization and balance sheet exposure have played during the 'Great Recession' one needs to find out which shocks are the most important drivers of international business cycles.

Furthermore, I find that the international transmission of capital quality shocks is quite robust to changes in the model while the cross-country correlation of GDP conditional on technology shocks changes its sign depending on the setup of the trade sector. The cross-country correlation of output for net worth shocks is always negative. These results cast some doubt on the explanatory power of technology shocks and net worth shocks with respect to the global scope of the recent financial crisis. Instead, my analysis suggests that incorporating capital quality shocks and international balance sheet exposure into a model with leverage-constrained financial intermediaries can help us to account for the high global comovement in real and financial variables in the recent past.

An obvious path for future research is to estimate a version of the model. Such an exercise will allow me to determine whether the transmission mechanisms I highlight in this theoretical work are empirically relevant. In particular, the theoretical exercise showed, that balance sheet exposure is essential for global comovement in the case of capital quality shocks. The latter have not entered the research agenda of the international business-cycle literature, yet. Therefore, I plan to contribute to existing research by analyzing the joint role of capital quality shocks and balance sheet exposure for the global scope of the recent economic crisis.

Chapter 3

Unconventional Monetary Policy in a Monetary Union

Abstract

I analyze the adoption of unconventional monetary policy measures in a monetary union. To this end, I lay out a two-country monetary union model with balance-sheet constrained financial intermediaries and central bank credit policy. The framework is used to compare the welfare implications of union-wide versus country-specific optimal simple unconventional monetary policy rules. It is shown that – despite the presence of country-specific shocks – country-specific rules are not necessarily associated with higher welfare from the viewpoint of a structurally symmetric union. Instead, to the extent that the central bank reacts to indicators which are highly correlated between countries, union-wide rules can be preferable. When considering structural asymmetries between countries, there is evidence that the introduction of unconventional monetary policy limits incentives to reform financial structures from the viewpoint of a financially less stable country.

Keywords: Unconventional Monetary Policy, Optimal Simple Rules, Welfare, Heterogeneous Monetary Union, Financial Frictions
JEL Classification: E44, E52, E58, F45

3.1 Introduction

It is widely known that joining a monetary union inevitably impairs the ability of monetary policy to address country-specific shocks. The common nominal interest rate adjusts proportionally to union-wide circumstances, which might cause either too much or too little stabilization in single countries. Furthermore, given that the nominal exchange rate between member countries is fix, nominal devaluations –

which have been occasionally used to prompt productivity in individual countries in the past – are ruled out.

This paper raises the question, whether it is desirable to use unconventional monetary policy to stabilize country-specific shocks in a monetary union. To this end, I lay out a two-country DSGE model with leverage-constrained financial intermediaries. The model features international trade in goods and assets, a common currency and a union-wide nominal interest rate. As in Gertler and Karadi (2011) and Gertler and Kiyotaki (2011), I assume that the common central bank can expand credit to banks ("liquidity facilities") and firms ("corporate sector purchase programs"). Unconventional policy is conducted by following a feedback rule which responds to financial indicators such as the credit spread or credit growth. In particular, I compare the welfare implications of optimal simple rules[1] based upon country-specific indicators to the corresponding outcomes under rules that are based upon union-wide indicators. In the baseline version of my model, I assume that countries are symmetric. However, structural heterogeneity is an important factor when discussing the conduct of unconventional policies in a monetary union. When some countries of a monetary union rely more heavily on central bank credit than others, while costs and risks are born by the union as a whole, incentives to reform financial structures might be misaligned. Therefore, I also consider a modified version of the model in which one country has a more sound financial system than the other. As the order of the approximation needs to be chosen in the light of the research question, the model is solved up to second-order.

A key finding of the analysis is that, under some circumstances, union-wide rules provide higher welfare than their country-specific counterparts despite the presence of country-specific shocks.[2] In particular, whenever the central bank reacts to indicators which are highly correlated between countries, a union-wide rule might be preferable over a country-specific rule. As in Dedola et al. (2013), this finding can be rationalized with the fact that I consider a second-best environment in which policymakers cannot fully eliminate financial frictions or their consequences. Unconventional monetary policy can reduce some of the additional volatility caused by financial frictions,[3] especially, in the economy hit by the shock. However, it can also fuel volatility by "overstabilizing" the country spared by the shock, especially when the unconventional instrument reacts to union-wide indicators. In general, a reduction in volatility is welfare-improving as it enhances consumption smoothing. On the other hand, in the second-best environment considered here, some degree of

[1] Optimal simple rules are feedback rules whose reaction coefficients are chosen such that the welfare of an individual household is maximized.

[2] Note that in the symmetric case, union-wide and country-specific welfare are perfectly proportional.

[3] The excess volatility caused by financial friction is a result of what is commonly referred to as "financial accelerator", i.e., the real effects of shocks originating in the real or financial sector are amplified due to the presence of financial frictions.

volatility interacts with the financial friction to stimulate precautionary behavior, such as precautionary saving and capital accumulation, which also has a positive effect on lifetime utility.[4] In the given setup, the trade-offs between the differing effects of unconventional monetary policy on average volatility and, further, between the differing effects of volatility on union-wide welfare can be tilted towards the positive or the negative depending on how the rule is formulated, i.e., which indicators the central bank reacts to.

When considering financially asymmetric countries – in particular, I consider the case in which one country has implemented a countercyclical capital buffer while the other country features an unregulated financial sector – I find that the introduction of unconventional monetary policy lowers the incentives to reform financial structures in the financially less regulated country.

The unconventional monetary policy measures analyzed in this paper represent instruments which are also part of the ECB's toolbox. Liquidity facilities have been one of the most important instruments of the ECB. Since 2008, liquidity was provided to the banking system elastically and at increasingly long durations through main and longer-term refinancing operations (MROs and LTROs) (Praet, 2017). Before and at the beginning of the financial crisis, Germany was the main user of these instruments (Bruegel, 2017). However, when the most significant three-year LTROs where provided in 2011 and 2012, the composition of country usage changed completely. Since 2011, the periphery's share in the usage of liquidity facilities has increased to more than 70% and has remained at this high level ever since (see figure 3.1). This implies that liquidity facilities where provided flexibly according to country-specific needs. The picture is quite different when considering the ECB's corporate sector asset purchase program which started in 2016. Direct lending to non-financial firms is distributed between countries in a fixed manner, according to a capital key which reflects the market value of eligible corporate bonds (ECB, 2017). Therefore, as figure 3.2 shows, mainly firms in the economically largest – and also less troubled – countries have access to central bank credit.

[4]Lester et al. (2014) and Cho et al. (2015) discuss further model features which can render volatility welfare-improving. Lester et al. (p. 18 2014) show that the "benefits of greater volatility are closely linked to the degree of elasticity in factor supplies." Hence, variable capital utilization and relatively elastic labor supply, which are both features of my model, might also contribute to the positive effects of volatility on welfare.

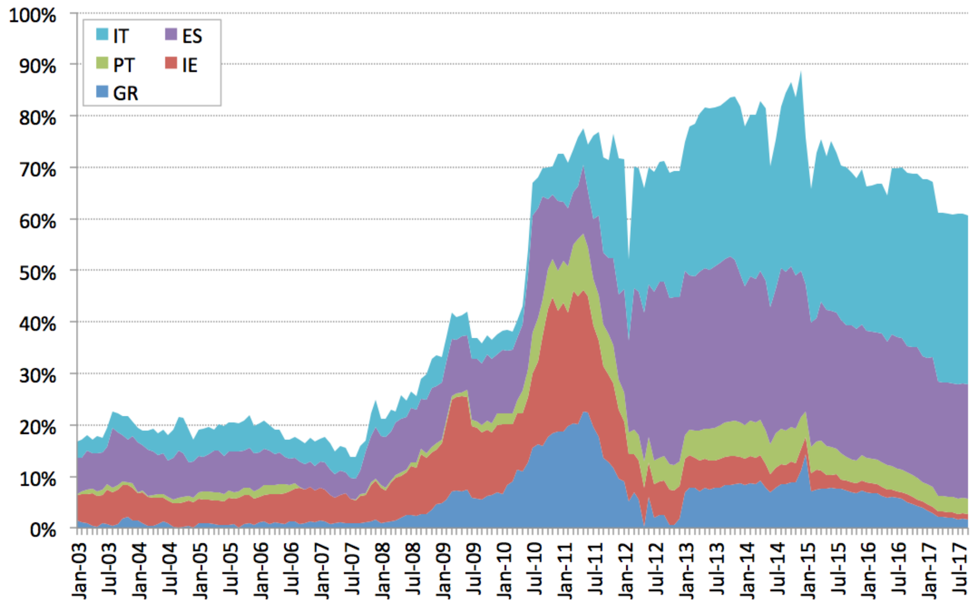

Figure 3.1: *Periphery's Share in the Usage of the Eurosystem's Main and Longer-Term Refinancing Operations 01/2003 - 09/2017; Bruegel (2017)*

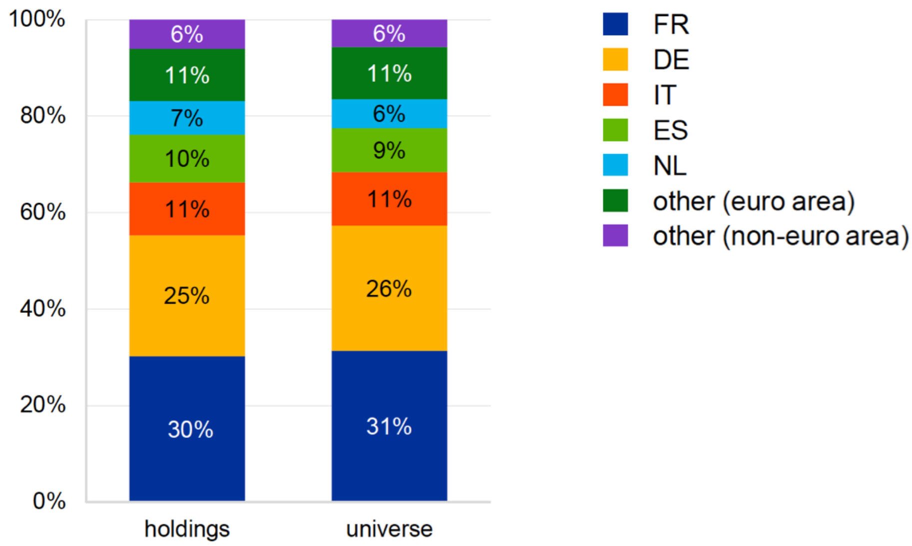

Figure 3.2: *Country Classification of Corporate Sector Purchase Program (CSPP) Holdings and CSPP-Eligible Bond Universe; ECB (2017)*

Given the extensive usage of non-standard measures by central banks around the world in recent years, there has been a surge in empirical and theoretical literature trying to analyze the economic effects of different unconventional policy measures. Employing DSGE models featuring a banking sector with financial frictions, Gertler and Karadi (2011), Gertler and Kiyotaki (2011) and Cúrdia and Woodford (2011) have shown that there are substantial gains from expanding central bank credit during crisis. Yet, as the analyses are based on closed economies, they are not well-suited to give advice on how the institutions of a currency union should cope with a financial crisis. Papers which analyze unconventional monetary policy in a two-country setting are usually interested in game theoretical issues associated with two separate monetary authorities interested in their own welfare functions (see, e.g., Dedola et al., 2013; Nuguer, 2016). The focus of my analysis is different. I omit game theoretical issues, for in a monetary union, it is reasonable to assume that a common monetary policy maker adopts a union-wide welfare function. As long as business cycles between member countries are less than perfectly correlated, it is, however, of great interest to analyze union-wide versus country-specific implementation of unconventional monetary policies. To my knowledge, there is only one paper by Tischbirek (2016) which addresses this kind of question, however, focuses on the effects of government debt purchases on fiscal policies. He uses a model which does not feature financial frictions. Further, Auray et al. (2016) use a version of the Gertler and Karadi (2011) model to analyze unconventional monetary policies in the Eurozone. However, they do not distinguish between country-specific and union-wide measures but are rather interested in strategies aimed at different financial market sectors. Schwanebeck (2017) uses the same structurally asymmetric two-country version of the Gertler and Karadi (2011) model as Nuguer (2016) (one country is a net borrower and the other is a net lender) to analyze the effects of unconventional monetary policy on the wholesale interbank market. However, he does not conduct a welfare analysis but focuses on positive policy implications.

To the extent of my knowledge, this paper is the first to analyze whether unconventional monetary policy can and should be used to stabilize country-specific shocks in a monetary union featuring – potentially heterogeneous – financial frictions.

The paper is organized as follows. The next section develops the model. Section 3.3 provides the calibration. In section 3.4, I will explain the welfare measure used. In section 3.5, I present and discuss the results on optimal simple rules in the baseline setup and in the case where one country features a more stable financial system than the other one. The final section concludes and gives an outlook.

3.2 Model

I assume that the world consists of two countries with symmetric structures which belong to a monetary union, each inhabited by a continuum of agents of equal size. The setup of each country closely resembles the setup of the closed economy modeled in Gertler and Karadi (2011), i.e., besides a banking system the model contains nominal (price stickiness) and real (habit formation, variable capital utilization) rigidities.

Each country features a financial intermediation sector. The role of intermediaries is to transfer funds between households and intermediate goods producers who use the loans to finance investment into physical capital. Intermediaries face an endogenously determined constraint on their leverage ratio, motivated by a simple agency problem which drives a wedge between saving and borrowing rates.

The two countries feature integrated markets for final goods, capital assets and deposits. To allow for these multiple interlinkages, I have to abstract from complete international consumption risk sharing. Allowing the net foreign asset position to be adjusted via two margins - equity and bond trade - might imply two unit roots in a first-order approximation of the model (see, e.g., Schmitt-Grohé and Uribe, 2003). Hence, I introduce two stationarity-inducing features, an endogenous discount factor, which dates back to Uzawa (1968), and a debt-elastic interest rate yield.

For simplicity only home country equations will be displayed. Foreign variables will be denoted with an asterisk.

3.2.1 Households

Within each household, there are two member types, workers and bankers. While the worker supplies work to intermediate goods firms and deposits to banks, the banker manages a financial intermediary and transfers retained earnings back to her household when the lifetime of the bank ends. Within the family, there is perfect consumption risk sharing, which allows to maintain the representative agent framework. As in Gertler and Karadi (2011), it is assumed that a fraction $1-f$ of household members are depositors, while a fraction f are bankers. Between periods there is a random turnover between the two groups: with probability θ_b a banker will stay a banker and with probability $1-\theta_b$ she will become a depositor. The relative proportions are kept fixed. New bankers are provided with some start-up funds from their respective households.

The lifetime utility of a representative home worker, who draws utility from consumption, C_t, and disutility from labor, L_t, is given by

$$E_t \sum_{k=0}^{\infty} \Theta_{t+k} \left(\ln(C_{t+k} - hC_{t+k-1}) - \chi \frac{L_{t+k}^{1+\phi}}{1+\phi} \right),$$

where parameter h determines the degree of habit formation, ϕ is the inverse of the Frisch elasticity of labor supply and χ determines the weight of disutility of labor in the utility function. Variable Θ_t represents the endogenous discount factor of households chosen to ensure stationarity as explained above.

Households save by depositing funds at domestic and foreign intermediaries (see 3.2.2 for details). Total deposits held between $t-1$ and t, denoted by D_{t-1}, are equivalent to one-period riskless real bonds paying the gross real rate of return R_{t-1}. Furthermore, households provide labor to intermediate goods firms and receive the real wage w_t. Hence, the representative home household's budget constraint in real terms is given by

$$C_t + D_t + T_t = R_{t-1}D_{t-1} + w_t L_t + \Upsilon_t,$$

where Υ_t denotes net profits from the ownership of firms (financial and non-financial) and T_t denotes lump-sum taxes.

Households have equal preferences for home and foreign final goods.[5] Hence, C_t, the CES composite of consumption, is given by

$$C_t = \left(0.5^{\frac{1}{\iota}} C_{H,t}^{\frac{\iota-1}{\iota}} + 0.5^{\frac{1}{\iota}} C_{F,t}^{\frac{\iota-1}{\iota}}\right)^{\frac{\iota}{\iota-1}},$$

with $\iota > 0$ and $C_{H,t}$ and $C_{F,t}$ denoting consumption of home and foreign final goods, respectively. The corresponding consumer price index takes the following form

$$P_t = \left(0.5 P_{H,t}^{1-\iota} + 0.5 P_{F,t}^{1-\iota}\right)^{\frac{1}{1-\iota}}, \tag{3.1}$$

where $P_{H,t}$ denotes the price of the home good in the home country and $P_{F,t}$ denotes the price of the foreign good in the home country.

Assuming local currency pricing, the law of one price holds, i.e., $P_{H,t} = P^*_{H,t}$ and $P_{F,t} = P^*_{F,t}$. As households preferences are identical in the two countries and no home bias is assumed, the consumption baskets are equal. Hence, Purchasing Power Parity holds and the real exchange rate is constant ($P_t = P^*_t$). The terms of trade are defined as the ratio between the price of exports and the price of imports, $ToT_t \equiv \frac{P_{H,t}}{P_{F,t}}$.

The endogenous discount factor is determined as follows

$$\begin{aligned}\Theta_{t+1} &= \Theta_t \beta(C_{A,t}),\\ \Theta_0 &= 1,\end{aligned}$$

where $C_{A,t}$ is aggregate home consumption. Using aggregate consumption in the endogenous discount factor ensures that the household does not internalize the effect of its consumption decision on the discount factor, which simplifies calculations considerably. As in Schmitt-Grohé and Uribe (2003) and Devereux and Yetman

[5]The main results of this paper are robust to changing this assumption, i.e., the results also hold when household consumption is biased towards home goods. However, the assumption of equal preferences simplifies the interpretation of results because real exchange fluctuations are absent.

(2010) the following functional form of the endogenous discount factor is assumed

$$\beta(C_{A,t}) = \omega_c(1 + C_{A,t})^{-\eta_c}. \tag{3.2}$$

Parameter η_c drives the elasticity of the discount factor with respect to consumption. Parameter ω_c captures the steady-state savings propensity. Note that the discount factor decreases in $C_{A,t}$, i.e., whenever a country has relatively higher consumption in the present, it discounts future consumption more heavily and, hence, saves less. The latter implies lower consumption in the future and, therefore, the economy returns to the initial state.

Hence, the household's first-order conditions for the optimal choice of labor and consumption are given by

$$w_t = \chi \frac{L_t^{\phi}}{\lambda_t}, \tag{3.3}$$

and

$$1 = \beta(C_{A,t}) E_t \Lambda_{t,t+1} R_t, \tag{3.4}$$

with the household's real stochastic discount factor being defined as

$$\Lambda_{t,t+1} \equiv \frac{\lambda_{t+1}}{\lambda_t}, \tag{3.5}$$

where λ_t denotes the marginal utility of consumption given by

$$\lambda_t = (C_t - hC_{t-1})^{-1} - \beta(C_{A,t})h(E_t C_{t+1} - hC_t)^{-1}. \tag{3.6}$$

3.2.2 International Intermediaries

To simplify matters, I implicitly assume that households hold deposits with international savings banks which – according to the needs in the financial system – channel the funds to home and foreign banks via international intermediaries. Total deposits of home households are given by $D_t = D_{H,t} + D_{F,t}$.

Allowing deposits to freely flow between countries, would induce a unit root. Therefore, it is assumed that home deposits can only be channeled to foreign banks by purchasing one-period bonds from international intermediaries. The latter charge a small interest rate premium on the union-wide nominal interest rate. The premium depends on the real net foreign bond position of the respective country. This assumption adds realism to the model and ensures stationarity (see, e.g., Schmitt-Grohé and Uribe, 2003). As in Hjortsoe (2016), I assume

$$i_t = i_t^{CB} \Phi(D_{F,t}), \tag{3.7}$$

where i_t^{CB} is the nominal interest rate set by the union-wide central bank and i_t is the country rate. It is assumed that the country-specific rate charged by international intermediaries is increasing in the deviation of the external household debt position (real debt is given by $-D_{F,t}$) from its steady state, i.e., $\Phi(\cdot)' < 0$ and $\Phi(0) = 0$. As in Hjortsoe (2016), the following functional form is chosen for the debt-elastic interest rate premium

$$\Phi(D_{F,t}) = (1 - \omega_d D_{F,t}).$$

Parameter ω_d is the yield sensitivity of debt.

Profits of international intermediaries are distributed to households within the current account surplus country. Note that rates of return on home deposits and bonds (equivalent to deposit holdings with foreign banks, $D_{F,t}$) are equalized due to arbitrage.

3.2.3 Banks

The setup of the banking sector closely follows Gertler and Karadi (2011) except for the modeling of the international dimensions. In the model economy, home financial intermediaries channel funds from households to home and foreign intermediate goods producers, fulfilling the double role of investment as well as commercial banks. In addition to obtaining funds from households, banks also raise funds internally by accumulating retained earnings. The balance sheet of home bank i is given by

$$B_{i,t} = D_{i,t}^B + N_{i,t}, \tag{3.8}$$

where $N_{i,t}$ denotes intermediary i's net worth. Deposits at bank i, stemming from home and foreign households, are denoted by $D_{i,t}^B = D_{iH,t} + D_{iH,t}^*$. The asset portfolio of bank i, $B_{i,t}$, consists of home as well as foreign assets which are combined according to the following CES aggregator[6]

$$B_{i,t} = \left(\mu_b^{\frac{1}{\iota_b}} (Q_t S_{iH,t})^{\frac{\iota_b - 1}{\iota_b}} + (1 - \mu_b)^{\frac{1}{\iota_b}} (Q_t^* S_{iF,t})^{\frac{\iota_b - 1}{\iota_b}} \right)^{\frac{\iota_b}{\iota_b - 1}}. \tag{3.9}$$

Variable $S_{iH,t}$ ($S_{iF,t}$) denotes the state-contingent claims on future returns of a unit of capital used in intermediate goods production in the home (foreign) economy.

[6]Assuming that the portfolio composition is determined by a CES aggregator allows to solve the model without using an endogenous portfolio choice method. The latter are associated with certain drawbacks such as inaccuracies when analyzing structurally asymmetric countries and at higher orders of approximation (cf. Rabitsch et al., 2015). Therefore, the usage of the CES function to determine international portfolios has become more and more popular in recent years (see, e.g., Auray et al., 2016; Poutineau and Vermandel, 2015; Brzoza-Brzezina et al., 2015; Dräger and Proaño, 2018).

The price of the claim is given by Q_t (Q_t^*). Parameter μ_b denotes home bias in portfolio holdings. Accordingly, the return on the portfolio, R_t^A, is determined by the following equation

$$\frac{1}{R_t^A} = \left(\mu_b \left(\frac{1}{R_{k,t}} \right)^{1-\iota_b} + (1-\mu_b) \left(\frac{1}{R_{k,t}^*} \right)^{1-\iota_b} \right)^{\frac{\iota_b}{\iota_b - 1}}, \tag{3.10}$$

where $R_{k,t}$ ($R_{k,t}^*$) denotes the state-contingent gross real rate of return of the home (foreign) capital asset. The banker chooses the optimal portfolio composition by maximizing expected portfolio returns subject to equation (3.9).[7]

Intermediary i's net worth evolves according to the following equation

$$N_{i,t} = R_t^A B_{i,t-1} - R_{t-1} D_{i,t-1}^B.$$

Since the banker cannot invest in assets which yield a discounted return smaller than the cost of borrowing, the following inequality has to be satisfied

$$E_t \beta(C_{A,t}) \Lambda_{t,t+1} (R_{t+1}^A - R_t) \geq 0.$$

With perfect capital markets the above relation would hold with equality. In the presence of financial frictions, however, the premium must be positive. It covaries negatively with output as the intermediary's inability to obtain funds increases during bad states of the economy. As long as the banker earns some positive yield on each unit of money invested, she finds it worthwhile to operate and further accumulate earnings.

It is assumed that each period a fraction 1-θ_b of bankers exit the business with i.i.d. probability and pay out accumulated earnings to their respective households.[8] Therefore, a banker maximizes the terminal value of her net worth given by

$$V_t = \max\ E_t \sum_{k=0}^{\infty} (1-\theta_b) \theta_b^k \Theta_{t+k} \Lambda_{t,t+k+1} N_{i,t+k+1}.$$

To motivate the requirement to build up net worth, the following moral hazard problem is assumed: At the beginning of each period, before the shocks realize and any other transactions take place, the banker can choose to divert the fraction λ_b of available funds back to the household. The cost associated with this fraud is that the depositors recover the remaining fraction $1 - \lambda_b$ and force the banker into bankruptcy. Therefore, for households to be willing to deposit funds with the bank,

[7] Details of the banker's CES portfolio choice problem and its solutions can be found in the appendix (section B.1).

[8] This arrangement precludes bankers from aggregating so much net worth that the incentive constraint becomes irrelevant for them.

the following incentive constraint must hold

$$V_{i,t} \geq \lambda_b B_{i,t}. \tag{3.11}$$

To solve the banker's maximization problem define the objective of the bank recursively as

$$V_{i,t} = \max \ E_t \beta(C_{A,t})\Lambda_{t,t+1}[(1-\theta_b)N_{i,t+1} + \theta_b V_{i,t+1}],$$

and conjecture that the franchise value is linear in assets and net worth

$$V_{i,t} = \nu_{i,t} B_{i,t} + \eta_{i,t} N_{i,t}.$$

The banker's problem consists in choosing the amount of total assets and deposits such that terminal net worth is maximized and the incentive constraint holds. It can be solved using the Lagrange method.[9]

The solutions for the coefficients are given by

$$\nu_t = E_t \Omega_{t,t+1}(R^A_{t+1} - R_t), \text{ and} \tag{3.12}$$

$$\eta_t = E_t \Omega_{t,t+1} R_t, \tag{3.13}$$

where

$$\Omega_{t,t+1} = \beta(C_{A,t})\Lambda_{t,t+1}\left[(1-\theta_b) + \theta_b\left(\eta_{t+1} + \nu_{t+1}\phi_{t+1}\right)\right], \tag{3.14}$$

which can be interpreted as the stochastic discount factor of the banker. It differs from the household's stochastic discount factor due to the presence of financial frictions. Note that the subscript i was dropped because the coefficients exclusively depend on aggregate variables.

Assuming that the incentive constraint binds,[10] it can be expressed in terms of the coefficients of the value function

$$B_t = \frac{\eta_t}{\lambda_b - \nu_t} N_t = \phi_t N_t, \tag{3.15}$$

where ϕ_t is the ratio of intermediated assets to net worth, which can be referred to as the leverage ratio. Note that it is determined endogenously in this model.

[9] The solution to the banks' problem is analogous to the one of the model presented in chapter 2. Detailed derivations can be found in section A.1 of the appendix to chapter 2.

[10] Parameters and steady-state values are chosen such that the incentive constraint binds in the steady state. Holding shocks small enough guarantees that the incentive constraint also binds in a stochastic environment.

Finally, the law of motion for aggregate net worth can be derived as

$$N_t = N_{n,t} + N_{e,t}\Xi_{N,t} \tag{3.16}$$

$$N_{e,t} = \theta_b \left[(R_t^A - R_{t-1})\phi_{t-1} + R_{t-1} \right] N_{t-1} \tag{3.17}$$

$$N_{n,t} = \omega_b B_{t-1}, \tag{3.18}$$

where $N_{e,t}$ denotes existing bankers' net worth, $N_{n,t}$ denotes new bankers' net worth and ω_b is the fraction of assets given to new bankers by households. Variable $\Xi_{N,t}$ denotes an exogenous disturbance to the net worth of existing bankers.

3.2.4 Intermediate Goods Firms

Intermediate goods firms produce an intermediate good which is sold to final goods producers in the same country at the real price $P_{m,t}$ for use in the production of the final good. The market for intermediate goods is assumed to be perfectly competitive. open The Cobb-Douglas production function of the representative intermediate goods firm is given by

$$Y_{m,t} = A_t(U_t\Psi_t K_{t-1})^{\alpha} L_t^{1-\alpha}, \tag{3.19}$$

where $Y_{m,t}$ denotes intermediary output, A_t exogenous technology and U_t the utilization rate of capital. Parameter α denotes the output elasticity of capital. Labor L_t is provided by households in the same country only. Capital K_{t-1} was bought from capital goods producers in the same country in the previous period at price Q_{t-1}. To finance capital purchases, the firm issues state-contingent securities to obtain funds from home and foreign intermediaries at the same price. Each period, after being productive, the firm has to pay back capital returns on the securities issued in the previous period. As in Gertler and Karadi (2011), I assume that there exists a shock to the quality of capital, denoted by Ψ_t, to provide a source for exogenous variations in the price of capital. It can be interpreted as the sudden realization that much of the capital installed is of lower quality than previously thought. As the capital stock is equal to the capital claims issued to banks, banks' balance sheets contract in response to a negative capital quality shock. The law of motion for capital is given by

$$K_t = I_t + (1 - \delta(U_t))\Psi_t K_{t-1}, \tag{3.20}$$

where I_t is aggregate investment and $\delta(U_t)$ denotes physical depreciation, where $\delta'(U_t) > 0$ and $\delta''(U_t) > 0$.

The first-order conditions of the intermediate goods producer's profit maximization problem are, therefore, given by[11]

$$R_{k,t+1} = \frac{\alpha \frac{P_{m,t+1} Y_{m,t+1}}{K_t} + (Q_{t+1} - \delta(U_{t+1}))\Psi_{t+1}}{Q_t}, \tag{3.21}$$

$$w_t = (1-\alpha)\frac{P_{m,t} Y_{m,t}}{L_t}, \tag{3.22}$$

and

$$\delta'(U_t)\Psi_t K_{t-1} = P_{m,t}\alpha \frac{Y_{m,t}}{U_t}. \tag{3.23}$$

The firm earns zero profits state-by-state, hence, it simply pays out the ex post return to capital $R_{k,t}$ to the financial intermediary.

3.2.5 Capital Goods Firms

Competitive capital goods firms produce capital only for the domestic market using national final output as input facing investment adjustment costs (in consumption units). I also follow the approach used by Gertler and Karadi (2011) and assume that adjustment costs are on net investment so that the capital utilization decision is independent of the market price of capital. Their functional form is given by

$$f\left(\frac{I_{n,t} + I}{I_{n,t-1} + I}\right) = \frac{\eta_I}{2}\left(\frac{I_{n,t} + I}{I_{n,t-1} + I} - 1\right)^2, \tag{3.24}$$

with $\eta_I > 0$, denoting the inverse elasticity of investment with respect to price of capital, I denoting steady-state investment and net investment being defined as $I_{n,t} \equiv I_t - \delta(U_t)\Psi_t K_{t-1}$. The capital goods producer chooses I_t to maximize lifetime profits given by

$$E_t \sum_{k=0}^{\infty} \Theta_k \Lambda_{t,t+k} \left\{ Q_{t+k} I_{t+k} - \left[1 + f(\cdot)\right] I_{t+k} \right\}.$$

From the first order conditions, the real price of one unit of capital is obtained

$$Q_t = 1 - f(\cdot) + \frac{I_{n,t} + I}{I_{n,t-1} + I} f'(\cdot) - E_t \beta (C_{A,t}) \Lambda_{t,t+1} \left(\frac{I_{n,t+1} + I}{I_{n,t} + I}\right)^2 f'(\cdot). \tag{3.25}$$

Due to flow investment costs, capital goods firms can earn profits outside the steady state. These profits are distributed lump-sum to the households.

[11] As in Gertler and Karadi (2011), I assume that the replacement price of depreciated capital is unity. Therefore, the value of the capital stock which is left over is given by $(Q_{t+1} - \delta(U_{t+1}))\Psi_{t+1} K_t$.

3.2.6 Final Goods Firms

Final output produced by home firms and purchased by consumers at home and abroad, Y_t, is assumed to be a CES composite of mass unity of differentiated final products

$$Y_t = \left[\int_0^1 Y_t(f)^{\frac{\epsilon-1}{\epsilon}} df\right]^{\frac{\epsilon}{\epsilon-1}},$$

with $0 < \epsilon$. $Y_t(f)$ denotes output by retailer f. The corresponding home producer price index is given by

$$P_{H,t} = \left[\int_0^1 P_{H,t}(f)^{1-\epsilon} df\right]^{\frac{1}{1-\epsilon}}.$$

Given that consumers allocate consumption expenditures optimally between varieties, home final goods firm f faces the following demand by home and foreign consumers[12]

$$Y_t(f) = \left(\frac{P_{H,t}(f)}{P_{H,t}}\right)^{-\epsilon} Y_t,$$

i.e., its share in total home final goods production, Y_t, depends on its relative price.

It is assumed that each unit of final output is assembled costlessly from one unit of intermediate output. Real marginal cost is therefore given by the intermediate output price $P_{m,t}$. It is further assumed that firms face a positive probability, θ, each period that they a are not able to reset their price (see Calvo, 1983). If not able to reset its price, a firm can partly index its price to the lagged rate of inflation. Hence, the optimal price of a representative home firm, $\tilde{P}_{H,t}$ is given by

$$\tilde{P}_{H,t} = \frac{\epsilon}{\epsilon - 1} \frac{E_t \sum_{k=0}^{\infty} \theta^k \Theta_k \lambda_{t+k} \Pi_{H,t,t+k}^{\epsilon} \Pi_{H,t-1,t+k-1}^{-\epsilon\theta_\pi} Y_{t+k} P_{m,t+k}}{E_t \sum_{k=0}^{\infty} \theta^k \Theta_k \lambda_{t+k} \Pi_{H,t,t+k}^{\epsilon-1} \Pi_{H,t-1,t+k-1}^{(1-\epsilon)\theta_\pi} Y_{t+k} p_{H,t+k}} P_{H,t}, \quad (3.26)$$

where $\Pi_{H,t} \equiv \frac{P_{H,t}}{P_{H,t-1}}$ denotes home producer price inflation between $t-1$ and t, $p_{H,t} \equiv \frac{P_{H,t}}{P_t}$ is the relative price of home goods and θ_π denotes the degree of price indexation. The dynamics of the home price index are given by

$$P_{H,t} = \left(\theta \Pi_{H,t-1}^{\theta_\pi(1-\epsilon)} P_{H,t-1}^{1-\epsilon} + (1-\theta)\tilde{P}_{H,t}^{1-\epsilon}\right)^{\frac{1}{1-\epsilon}}. \quad (3.27)$$

3.2.7 Interest Rate Policy

Interest rate policy is specified by a standard Taylor rule. It is assumed that the common central bank reacts to variations in the union-wide output gap and the consumer price index (CPI). The union-wide output gap is determined as a weighted

[12]Under the assumption of local currency pricing (which preserves the Law of one Price), a distinction between home and foreign demand is not necessary.

average of the country-specific output gaps. Given that Purchasing Power Parity holds, consumer price inflation is the same among both countries, i.e., $\Pi_t = \Pi_t^*$, where $\Pi_t = \frac{P_t}{P_{t-1}}$ denotes consumer price inflation between periods $t-1$ and t. CPI targeting is chosen, because it represents a better description of actual Taylor rules used in central banks following inflation targeting strategies (Devereux et al., 2014, p. 937). The particular Taylor rule of the central bank is given by

$$i_t^{CB} = \left(\beta \Pi_t^{\gamma_\pi} \hat{y}_t^{0.5\gamma_y} \hat{y}_t^{*0.5\gamma_y}\right)^{1-\rho_i} \left(i_{t-1}^{CB}\right)^{\rho_i} \varepsilon_{M,t}, \tag{3.28}$$

where β is the steady-state discount factor and $\hat{y}_t$ ($\hat{y}_t^*$) denotes the domestic (foreign) output gap, defined as the difference between flexible price output and sticky price output. The output gap is approximated by the inverse of the markup gap.[13] The monetary disturbance is denoted by $\varepsilon_{M,t}$.

The Fisher equation establishes the link between the country-specific nominal and real interest rates, i.e.,

$$i_t = R_t E_t \Pi_{t+1}, \tag{3.29}$$

where the link between the country-specific nominal rate, i_t, and the union-wide policy rate, i_t^{CB}, is given by equation (3.7).

Note that I do not assume that conventional monetary policy acts to accommodate unconventional policy. Cahn et al. (2014) model an accommodating interest rate policy and find that, in this case, the effects of unconventional policy are much larger.

3.2.8 Unconventional Policies

In this paper, I analyze the impact of two kinds of unconventional monetary policy, in particular, liquidity facilities and private sector credit purchases. Both types of policies are modeled using simple rules.

Liquidity Facilities

In the European Union, since the end of 2008, liquidity facilities are conducted under the fixed rate full allotment tender procedure, i.e., the ECB sets the interest rate and elastically supplies any amount of liquidity financial institutions ask for. The model cannot directly replicate this policy feature as the central bank in the model chooses the quantity of funds by following a feedback rule. However, rule-based liquidity injections capture the endogeneity of the balance sheet expansion to some extent as they imply that the supply of central bank credit reacts elastically to prevailing market conditions (Cahn et al., 2014).

[13] In the given setup, the markup is given by $\frac{p_{H,t}}{P_{m,t}}$, where $p_{H,t} \equiv \frac{P_{H,t}}{P_t}$.

The central bank can lend funds, denoted by M_t, directly to banks at rate $R_{m,t}$. As proposed by Gertler and Kiyotaki (2011), it is assumed that the central bank has superior enforcement possibilities compared to households, hence, only the fraction $\lambda_b(1-\lambda_m)$ with $0 < \lambda_m < 1$ of central bank assets can be diverted.[14] Given these assumptions, a home intermediary's balance sheet takes the following form

$$B_{i,t} = D^B_{i,t} + N_{i,t} + M_{i,t}. \tag{3.30}$$

The equation for the evolution of intermediary i's net worth needs to be replaced by the following equation

$$N_{i,t} = R^A_t B_{i,t-1} - R_{t-1} D^B_{i,t-1} - R_{m,t-1} M_{i,t-1}.$$

The incentive constraint (formerly defined by equation (3.11)) is now given by

$$V_{i,t} \geq \lambda_b (B_{i,t} - \lambda_m M_{i,t}). \tag{3.31}$$

Taking into account the modified balance sheet and incentive constraint, the net cost of an extra unit of liquidity facilities is given by

$$\eta_{m,t} = E_t \Omega_{t,t+1} (R_{m,t} - R_t). \tag{3.32}$$

From the first order conditions of the modified bank's problem, it can be further derived that

$$\eta_{m,t} = \lambda_m \nu_t, \tag{3.33}$$

which ties down $R_{m,t}$. The law of motion for existing banks' net worth (formerly defined by equation (3.17)) changes to

$$N_{e,t} = \theta_b \left[(R^A_t - R_{t-1}) \frac{\phi_{t-1}}{1 - \lambda_m \Phi_{m,t-1}} - (R^m_{t-1} - R_{t-1}) \frac{\phi_{t-1} \Phi_{m,t-1}}{1 - \lambda_m \Phi_{m,t-1}} + R_{t-1} \right] N_{t-1}, \tag{3.34}$$

where $\Phi_{m,t}$ denotes the fraction of home bank assets intermediated by the central bank, i.e.,

$$M_t = \Phi_{m,t} B_t. \tag{3.35}$$

As already discussed, I use a rule-based approach to model the provision of liquidity facilities. The fractions of intermediated assets in the home and foreign

[14] If the fraction of divertable assets would be the same for central bank funds as for household deposits, the extra credit would not expand the supply of liquidity in the banking market but simply supplant it.

economy, $\Phi_{m,t}$ and $\Phi^*_{m,t}$, respectively, are determined by simple rules. In particular, I distinguish between union-wide versus country-specific rules and credit spread (rule 1) versus credit growth (rule 2) rules. If a union-wide rule is chosen, the central bank adjusts $\Phi_{m,t} = \Phi^*_{m,t}$ in reaction to union-wide averages, whereas, when a country-specific rule is chosen, it holds that $\Phi_{m,t} \neq \Phi^*_{m,t}$, whenever the economy is not in the deterministic steady state.[15] Note that an increase in the credit spread and a decrease in credit growth indicate a tightening of financial conditions caused by an adverse shock. Hence, the fractions of intermediated assets, $\Phi_{m,t}$ and $\Phi^*_{m,t}$, are either directly proportional to the deviation of the external finance spread[16] from its steady-state value (credit spread rule) or inversely proportional to credit growth (credit growth rule).

Hence, the *union-wide rule* is either given by

$$\Phi_{m,t} = \kappa_m \left[0.5\left(\ln\left(\frac{R_{k,t}}{R_t}\right) + \ln\left(\frac{R^*_{k,t}}{R^*_t}\right)\right) - \ln\left(\frac{R_k}{R}\right)\right] \tag{3.36}$$

or

$$\Phi_{m,t} = -\kappa_m \ln\left[\frac{0.5(Q_t K_t + Q^*_t K^*_t)}{0.5(Q_{t-1}K_{t-1} + Q^*_{t-1}K^*_{t-1})}\right]. \tag{3.37}$$

The *country-specific rules* are either given by

$$\Phi_{m,t} = \kappa_m \left[\ln\left(\frac{R_{k,t}}{R_t}\right) - \ln\left(\frac{R_k}{R}\right)\right], \tag{3.38}$$

$$\Phi^*_{m,t} = \kappa_m \left[\ln\left(\frac{R^*_{k,t}}{R^*_t}\right) - \ln\left(\frac{R_k}{R}\right)\right], \tag{3.39}$$

or

$$\Phi_{m,t} = -\kappa_m \ln\left[\frac{Q_t K_t}{Q_{t-1}K_{t-1}}\right], \tag{3.40}$$

$$\Phi^*_{m,t} = -\kappa_m \ln\left[\frac{Q^*_t K^*_t}{Q^*_{t-1}K^*_{t-1}}\right]. \tag{3.41}$$

[15] I only consider uncorrelated country-specific shocks. If shocks were perfectly correlated between the two economies, it would also hold in the presence of shocks that $\Phi_{m,t} = \Phi^*_{m,t}$.

[16] Note that I use the same definition of the external finance premium as Gertler and Karadi (2011), i.e., the difference between financing costs of firms and the deposit rate. In their model, this spread coincides with the spread relevant for banks. With banking market integration, I could alternatively use $\ln R^A_{t+1} - \ln R_t$, reflecting more closely the conditions in the banking sector. Although I do not expect results to differ much, I plan to include such an analysis into the robustness checks.

Corporate Sector Credit Policy

The second type of unconventional monetary policy is the direct provision of non-financial private sector credit by the central bank (see also, e.g., Gertler and Karadi, 2011; Dedola et al., 2013). I assume that the central bank intermediates fraction $\Phi_{f,t}$ of overall funding needs in the home economy, i.e.,

$$F_t = \Phi_{f,t} Q_t K_t, \tag{3.42}$$

where F_t denotes overall private sector asset purchases by the central bank in the home economy. Hence, the capital market clearing condition, equation (3.52), which will be provided in the next section, has to account for the fraction of publicly intermediated assets.

As before, I distinguish between union-wide versus country-specific and credit spread (rule 1) versus credit growth (rule 2) rules. And it also holds that whenever the central bank choses a union-wide rule, the same fraction of private sector assets is provided in each country, i.e., $\Phi_{f,t} = \Phi^*_{f,t}$.

Therefore, the *union-wide rule* is either given by

$$\Phi_{f,t} = \kappa_f \left[0.5 \left(\ln\left(\frac{R_{k,t}}{R_t}\right) + \ln\left(\frac{R^*_{k,t}}{R^*_t}\right) \right) - \ln\left(\frac{R_k}{R}\right) \right] \tag{3.43}$$

or by

$$\Phi_{f,t} = -\kappa_f \ln\left(\frac{0.5(Q_t K_t + Q^*_t K^*_t)}{0.5(Q_{t-1} K_{t-1} + Q^*_{t-1} K^*_{t-1})} \right). \tag{3.44}$$

The *country-specific rules* are either given by

$$\Phi_{f,t} = \kappa_f \left[\ln\left(\frac{R_{k,t}}{R_t}\right) - \ln\left(\frac{R_k}{R}\right) \right], \tag{3.45}$$

$$\Phi^*_{f,t} = \kappa_f \left[\ln\left(\frac{R^*_{k,t}}{R^*_t}\right) - \ln\left(\frac{R_k}{R}\right) \right], \tag{3.46}$$

or by

$$\Phi_{f,t} = -\kappa_f \ln\left(\frac{Q_t K_t}{Q_{t-1} K_{t-1}}\right), \tag{3.47}$$

$$\Phi^*_{f,t} = -\kappa_f \ln\left(\frac{Q^*_t K^*_t}{Q^*_{t-1} K^*_{t-1}}\right). \tag{3.48}$$

Public Intermediation Costs and Government Budget Constraint
I assume that central bank intermediation is costly. These costs could capture efficiency costs but also the risk of credit default whose actual occurrence is ruled out in this kind of model. I follow Gertler et al. (2012) and Dedola et al. (2013) in assuming quadratic intermediation costs. This kind of modeling reflects the more realistic scenario where costs are higher whenever the central bank has a long position in corporate assets or bank credit (Gertler et al., 2012). The cost functions are given by

$$\Gamma_{m,t} = \tau_1(M_t + M_t^*) + \tau_2(M_t^2 + M_t^{*2}), \tag{3.49}$$
$$\Gamma_{f,t} = \tau_1(F_t + F_t^*) + \tau_2(F_t^2 + F_t^{*2}), \tag{3.50}$$

where $\Gamma_{m,t}$ and $\Gamma_{f,t}$ denote the total costs of central bank intervention and τ_1 and τ_2 reflect the sensitivity of the costs with respect to the amount of central bank credit provided.

Central bank credit to financial and non-financial firms is financed by the issuance of government debt which is a perfect substitute for household deposits. I assume that in each country the amount of central bank credit is equal to the issuance of government debt. Thereby, the aggregate resource constraint is not affected by unconventional monetary policy. Furthermore, I assume that costs are equally split between the two countries. Hence, the home government flow budget constraint takes the following form

$$0.5(\Gamma_{m,t} + \Gamma_{f,t}) + M_t + F_t = T_t + (R_{m,t-1} - R_{t-1})M_{t-1} + (R_{k,t} - R_{t-1})F_{t-1}. \tag{3.51}$$

3.2.9 Market Clearing and Further Equilibrium Conditions

The capital market clearing condition states that in each country, the current value of total installed capital has to be equal to the total value of state-contingent claims on future returns of capital. If the central bank provides corporate sector credit, the fraction of funds intermediated by the central bank, $\Phi_{f,t}$, has to be deducted

$$(1 - \Phi_{f,t})Q_t K_t = Q_t(S_{H,t} + S_{H,t}^*). \tag{3.52}$$

Home final goods market clearing is given by

$$Y_t = C_{H,t} + C_{H,t}^* + \frac{P_t}{P_{H,t}}[I_t + f\left(\frac{I_{n,t} + I}{I_{n,t-1} + I}\right)(I_{n,t} + I)]. \tag{3.53}$$

The home aggregate resource constraint is derived from aggregation of home households' budget constraints, considering profits from the ownership of non-financial firms, profits of international intermediaries, the government flow budget constraint, retained earnings from exiting bankers and the transfer to new bankers

$$\begin{aligned}\frac{P_{H,t}}{P_t}Y_t + Q^*_{t-1}S_{F,t-1}R^*_{k,t} - Q_{t-1}S^*_{H,t-1}R_{k,t} + D_{F,t-1}\frac{i_{t-1}}{\Pi_t} + \Upsilon^{\text{IFI}}_t \\ = C_t + D_{F,t} + \left[I_t + f\left(\frac{I_{n,t}+I}{I_{n,t-1}+I}\right)(I_{n,t}+I)\right] \\ +Q^*_t S_{F,t} - Q_t S^*_{H,t} + 0.5(\Gamma_{m,t} + \Gamma_{f,t}),\end{aligned} \tag{3.54}$$

where $\Upsilon^{\text{IFI}}_t = -\left(\frac{1}{\Phi(-D_{F,t})} - 1\right)\frac{D_{F,t}}{i^{CB}_t}$ denotes international intermediaries' profits.[17]

Bonds are in zero net supply, i.e.,

$$D_{F,t} = -D^*_{H,t},$$

where $D^*_{H,t}$ denotes foreign households' deposits in home banks or, more specifically, foreign international bond holdings invested in home banks.

Last but not least, the relationship between final goods production and intermediate goods production characterizes the equilibrium

$$Y_{m,t} = Y_t \Delta_{p,t}, \tag{3.55}$$

with $\Delta_{p,t}$ denoting the price dispersion which arises in a model with a two-stage production process with intermediate and final good producers and sticky prices à la Calvo. It can be written in terms of producer price inflation

$$\Delta_{p,t} \quad = \quad \theta\Delta_{p,t-1}\Pi^{\epsilon}_{H,t}\Pi^{-\epsilon\theta_\pi}_{H,t-1} + (1-\theta)\left(\frac{1-\theta\Pi^{\epsilon-1}_{H,t}\Pi^{\theta_\pi(1-\epsilon)}_{H,t-1}}{1-\theta}\right)^{\frac{\epsilon}{\epsilon-1}}. \tag{3.56}$$

The full set of equilibrium equations of the model can be found in the appendix (section B.2).

3.3 Calibration

Table 3.1 reports the baseline calibration and its sources. The time unit is one quarter.

The values for the habit formation parameter, h, the Frisch elasticity of labor supply, ϕ^{-1}, the steady-state depreciation rate, $\delta(U)$, the elasticity of marginal depreciation with respect to the utilization rate, ζ, the inverse elasticity of net

[17]As in Hjortsoe (2016), I assume that international intermediaries' profits are redistributed in a lump-sum fashion to households in the current account surplus country.

investment to the price of capital, η_I and the Calvo parameter, θ, are taken from Gertler and Karadi (2011). They report to base most of them on estimates from Primiceri et al. (2006).

Parameter η_c in the endogenous discount factor was taken from Devereux and Sutherland (2009). They choose it to be small, to keep the effects of this purely technical feature on the results of the model negligible. The same is true for ω_d, the yield sensitivity to debt, which is calibrated as in Hjortsoe (2016). Given $\eta_c = 0.01$ and the steady-state value of consumption, parameter ω_c was chosen as to guarantee an annual steady-state interest rate of 4%, i.e., a steady-state value of $\beta(C_A)$ of 0.99.

Parameter b, which appears in the equation for variable capital utilization (see equation (B.35) in the appendix), was chosen such that the steady-state capital utilization rate is equal to one. Given b, parameter δ_u was chosen as to guarantee a steady-state depreciation rate of 0.025.

The value chosen for the trade elasticity between home and foreign goods is in line with the values de Walque et al. (2006) estimated for the European Union. Home bias in asset holdings, μ_b, and the elasticity of substitution between home and foreign assets, ι_b, were taken from Poutineau and Vermandel (2015) who estimated them based on Eurozone data. Note that the value of ι_b determines the degree of synchronization between home and foreign asset returns.

The values of the parameters of the banking system, λ_b, θ_b and ω_b are taken from Gertler and Karadi (2011). They choose these values to hit three targets: a steady-state interest rate spread of 100 basis points, a steady-state leverage ratio of four and an average lifetime of a bank of 10 years.

The coefficients of the Taylor rule, γ_y and γ_π, were also taken from Gertler and Karadi (2011). Parameter λ_m was chosen to yield a divertability of government assets of approximately 0.2 ($= \lambda_b(1 - \lambda_M)$), which is, admittedly, an arbitrary value. The intermediation cost parameters, τ_1 and τ_2, are taken from Gertler et al. (2012).[18] The feedback coefficients of the unconventional monetary policy rules will be chosen optimally.

The three exogenous variables A_t, Ψ_t and $\Xi_{N,t}$ are assumed to follow AR(1) processes. Persistency and standard deviation of the technology shock are taken from Gertler and Karadi (2011). The persistency of the net wealth shock is set to 0.66 which is equal to the persistency of the capital quality shock. Note that the capital quality shock as well as the net wealth shock directly affect stock variables and, hence, feature a high endogenous persistency. The size of the capital quality shock is set equal to the size of the other shocks.

[18]As there is no information on the cost of central bank credit policy, however, the modeling of these costs directly affects the welfare results, robustness checks were conducted. I found that the main result is not qualitatively affected by choosing considerably higher values of τ_1 and τ_2. The corresponding welfare tables can be found in section B.4 of the appendix.

Parameter	Description	Value	Source
Households			
h	habit formation parameter	0.815	Gertler and Karadi (2011)
χ	utility weight of labor	2.592	
ϕ	inverse of Frisch elasticity	0.276	Gertler and Karadi (2011)
η_c	parameter from discount factor	0.010	Devereux and Sutherland (2009)
ω_c	parameter capturing steady-state savings propensity	0.996	
ω_d	yield sensitivity to debt	0.010	Hjortsoe (2016)
Capital producing firms			
η_I	inverse elasticity of investment with respect to price of capital	1.728	Gertler and Karadi (2011)
Intermediate goods firms			
α	output elasticity of capital	0.330	Gertler and Karadi (2011)
$\delta(U)$	steady-state depreciation rate	0.025	Gertler and Karadi (2011)
ζ	elasticity of marginal depreciation with respect to utilization rate	7.200	Gertler and Karadi (2011)
b	parameter from variable capital utilization	0.038	
δ_u	parameter from variable capital utilization	0.020	
Final goods firms			
θ	probability of keeping prices fixed	0.779	Gertler and Karadi (2011)
θ_π	degree of price indexation	0.241	Gertler and Karadi (2011)
ϵ	elasticity of substitution between varieties	4.167	Gertler and Karadi (2011)
ι	elasticity of substitution between home and foreign goods	4.000	de Walque et al. (2006)
Financial intermediaries			
λ_b	fraction of divertable assets	0.381	Gertler and Karadi (2011)
ω_b	transfer to entering banks	0.002	Gertler and Karadi (2011)
θ_b	quarterly survival rate of banks	0.972	Gertler and Karadi (2011)
ι_b	elasticity of substitution between home and foreign assets	2.020	Poutineau and Vermandel (2015)
μ_b	steady-state home bias in asset holdings	0.910	Poutineau and Vermandel (2015)
Central bank			
γ_y	feedback coefficient on output gap	0.125	Gertler and Karadi (2011)
γ_π	feedback coefficient on inflation	1.500	Gertler and Karadi (2011)
ρ_i	interest rate smoothing coefficient	0.800	Gertler and Karadi (2011)
λ_m	parameter to determine divertability of central bank funds	0.500	
κ_m	feedback coefficient from liquidity facilities rule	-	
κ_f	feedback coefficient from credit policy rule	-	
τ_1	CB intermediation cost parameter	0.000125	Gertler et al. (2012)
τ_2	CB intermediation cost parameter	0.001200	Gertler et al. (2012)
Exogenous processes			
ρ_ψ	persistence of capital quality shock	0.66	Gertler and Karadi (2011)
ρ_A	persistence of technology shock	0.95	Gertler and Karadi (2011)
ρ_N	persistence of net wealth shock	0.66	
σ_ψ, σ_N, σ_A, σ_M	standard deviation of shocks	0.01	

Table 3.1: *Parameters*

3.4 Welfare Measure

Welfare is evaluated by first computing the conditional expected lifetime utility of the representative household under each financial market setting, as proposed by Schmitt-Grohé and Uribe (2004). The advantage of using conditional welfare is that it takes into account the transition to a particular, regime specific, stochastic steady state.[19] In the upcoming analyses, all regimes are associated with different stochastic steady states. Welfare is conditioned on the initial state being the deterministic steady state, which is the same in all scenarios. Steady state welfare is given by

$$\overline{W} = \frac{U(\overline{C}, \overline{L})}{1 - \beta(\overline{C})} = \frac{\ln((1-h)\overline{C}) - \chi\frac{\overline{L}^{1+\phi}}{1+\phi}}{1 - \omega_c(1+\overline{C})^{-\eta_c}}.$$

The conditional expectation of lifetime utility as of time 0 of a particular regime is denoted as

$$W_0 = E_0 \sum_{k=0}^{\infty} \beta(C_{A,t+k}) \left(\ln(C_{t+k} - hC_{t+k-1}) - \chi \frac{L_{t+k}^{1+\phi}}{1+\phi} \right).$$

The benefit or loss of a particular policy regime is calculated as the permanent change in steady-state consumption, necessary to make agents in the non-stochastic steady state as well off as those in the stochastic economy. I define the necessary permanent change in steady-state consumption as g. A positive value of g means that agents in the stochastic setting are better off, whereas a negative value implies that agents in the non-stochastic setting have a higher welfare. The particular value for g is found by solving the following equation:

$$W_0 = \frac{\ln((1+g)(1-h)\overline{C}) - \chi\frac{\overline{L}^{1+\phi}}{1+\phi}}{1 - \omega_c(1+(1+g)\overline{C})^{-\eta_c}}.$$

Conditional welfare is calculated with Dynare. Following, e.g., Gertler and Karadi (2011), I write welfare recursively as

$$W_t = U(C_t, L_t) + \beta(C_{A,t})E_t W_{t+1},$$

into the model block and take a second-order approximation of the whole model. From the output I take the uncertainty correction of variable W_t and add it to the deterministic steady state.[20]

[19]I define the stochastic steady state as the point in the state space where agents decide to stay in the absence of shocks, but taking into account the distribution of future shocks (cf. Juillard and Kamenik, 2005).

[20]This procedure is described in the Dynare Forum (see Pfeiffer, 2016).

For each type of policy – liquidity facilities and credit policy, credit spread and credit growth rule, union-wide and country-specific rule – I search for the optimal rule by searching numerically for the value of κ_m or κ_f which yields the highest conditional welfare. I restrict the values of the reaction coefficients to lay in the interval of $[0, 330]$. Gertler and Karadi (2011) call a rule with $\kappa_f = 100$ “aggressive policy”, hence, parameter values which lay even above 100 can be seen as very unrealistic. However, this paper is just a first step towards a deeper analysis of unconventional monetary policy in a monetary union and also a wide arrange of rules is analyzed, therefore, on purpose, the interval was chosen to be very wide as well.

3.5 Results

In this section, I first present and discuss the welfare implications of the different types of unconventional monetary policy introduced in section 3.2.8, from the viewpoint of a structurally symmetric union. In oder to better understand what drives these results, I conduct further model analyses, which are presented in subsection 3.5.2. In particular, I discuss the impulse responses for the home and foreign economy under different unconventional monetary policies and I analyze the sensitivity of my results to varying certain model features which are responsible for the cross-country correlations of the indicator variables. In the last subsection, I turn to a monetary union, in which one country has already implemented a countercyclical capital buffer and analyze whether the introduction of unconventional monetary policy distorts the incentives to introduce the same macroprudential regulation in the other country.

3.5.1 Optimal Simple Rules in a Symmetric Setup

Table 3.2 displays the results for the different policy regimes. First, it should be noted, that all types of policies analyzed here can be welfare-improving compared to the case of no unconventional policy (relative gain is always positive). However, this is not a general result but depends, most importantly, on the presence and calibration of specific shocks in the model, the calibration of λ_m and the assumptions regarding the intervention costs.[21]

Furthermore, it can be seen that in all cases, credit policy yields higher welfare than the provision of liquidity facilities. The reason is that in the case of credit policy, the central bank directly provides credit to the corporate sector, while in the case of liquidity facilities, the funds provided by the central bank are channeled

[21] As the robustness analysis in section B.4 of the appendix shows, even for very high intervention cost parameters ($\tau_1 = 0.000625$ and $\tau_2 = 0.0062$) most policies are still welfare-improving.

	κ_f, κ_m (1)	g (2)	Rel. gain (3)	Risk-sharing (4)	K (5)	N (6)	C (7)	vol(C) (8)	L (9)	vol(L) (10)
No UMP	-	-3.69	-	0.70	5.609	1.524	0.702	0.0606	0.331	0.0803
Rule 1 - Credit Spread Rule										
LF, cou.	59	-3.22	0.47	0.66	5.646	1.512	0.704	0.0541	0.332	0.0485
LF, un.	73	-3.15	0.53	0.64	5.653	1.504	0.705	0.0538	0.332	0.0470
CCP, cou.	182	-2.23	1.46	0.67	5.667	1.258	0.705	0.0483	0.332	0.0367
CCP, un.	231	-2.09	1.59	0.61	5.674	1.170	0.706	0.0490	0.332	0.0358
Rule 2 - Credit Growth Rule										
LF, cou.	63	2.50	6.19	0.68	5.973	1.297	0.713	0.0525	0.332	0.0562
LF, un.	69	2.28	5.97	0.66	5.951	1.308	0.713	0.0526	0.333	0.0543
CCP, cou.	132	4.17	7.85	0.74	6.077	1.211	0.717	0.0454	0.334	0.0567
CCP, un.	132	3.78	7.46	0.64	6.047	1.229	0.717	0.0476	0.334	0.0546

No UMP: no unconventional monetary policy. LF: liquidity facilities. CCP: corporate credit policy. Cou.: country-specific. Un.: union-wide. κ_f: optimal feedback coefficient for liquidity facilities. κ_m: optimal feedback coefficient for credit policy. g: welfare gains in consumption equivalents in percent of steady-state consumption. Relative gain: difference in g to case without unconventional policy. International risk-sharing is measured as corr(λ_t, λ_t^*). Columns (5)-(7) and (9) display the stochastic steady state of the given variable.

Table 3.2: *Optimal Simple Rules in a Symmetric Setup*

through the private financial intermediation sector which is subject to financial frictions.[22] This can also explain, why it is optimal to conduct credit policy much more aggressively than the provision of liquidity facilities ($\kappa_f > \kappa_m$ for each rule).[23]

A further result is, that credit growth rules yield higher welfare than credit spread rules. As the positive g implies, when living in an environment in which the central bank conducts unconventional policies following credit spread rules, a household even prefers a stochastic over a deterministic environment.[24] Assumably, the reason is that credit growth is more closely related to welfare-relevant, i.e., real variables than the credit spread. Moreover, the credit spread should be reflected in credit growth while credit growth contains additional information about the state of the (real) economy.

[22] Rewriting the banking sector's balance sheet in the presence of liquidity facilities as

$$B_t = \phi_t N_t + \lambda_m M_t,$$

it is straightforward to see that of each unit of central bank funds provided, only $\lambda_m < 1$ are turned into credit.

[23] If one is interested in a direct welfare comparison between these two types of measures, it might be recommendable to set intervention costs higher for corporate credit policy, given that corporate asset purchases presumably require a higher amount of monitoring activities by the central bank.

[24] As discussed in the introduction to this chapter, in this type of model, a certain degree of volatility can be welfare-improving as it interacts with the financial friction to stimulate precautionary behavior, which, generally, results in a higher stochastic steady state capital stock. The latter permits higher consumption in the stochastic steady state.

The most interesting finding is that whenever the central bank uses a credit spread rule, welfare is higher when the central bank reacts to union-wide averages than when it reacts to country-specific indicators. The opposite holds when the central bank relies on a credit growth rule. In this case, country-specific rules are better suited to address country-specific disturbances. In the next section, I will provide some additional analyses in order to find an explanation for this result.

Table 3.2 also reports consumption risk-sharing between the two countries, the stochastic steady-state values of capital (K), bankers' net worth (N), consumption (C) and labor (L)[25] and consumption and labor volatility. It is interesting to see that the welfare results are not – or only marginally – driven by consumption risk-sharing. Although welfare is lowest in the case without unconventional monetary policy, international risk-sharing ranks second among all regimes. For each rule and policy, – quite plausibly – risk-sharing is higher when the policy maker reacts to country-specific indicators, however, as has been discussed before, welfare is not necessarily higher for country-specific policy. It should further be noted, that welfare is positively related to the stochastic steady-state capital stock. On the other hand, in most cases, welfare is higher when banking net worth is lower. Taken together, these two findings reflect that unconventional policy is successful in reducing financial frictions which allows banks to hold less net worth, freeing resources which can be shifted towards the buildup of a higher capital stock. Labor slightly increases with a higher capital stock, due to the assumption of a Cobb-Douglas production technology. A higher capital stock allows higher consumption in the stochastic steady state which can partly explain welfare differences. However, the table also shows that – up to three digits – stochastic steady-state consumption does not differ between the country-specific and the union-wide conduct of a particular unconventional policy rules. Consumption volatility is generally higher for union-wide rules, except if the central bank provides liquidity facilities in reaction to the credit spread.

3.5.2 Understanding the Results

As it is well know, welfare results are – to a large extent – driven by the underlying sources of risk. Therefore, when trying to understand the results, it is advisable to look at the optimal simple rules in environments featuring only one shock at a time. Tables B.1 to B.4 in appendix B contain the respective coefficients and welfare results. It can be easily seen that the capital quality shock drives the main results. This shock is quite powerful and enters the model in different ways. First, capital quality shocks perfectly resemble technology shocks with respect to their

[25] The stochastic steady state is computed by simulating the model forward without shocks using the policy functions obtained from a second-order approximation of the model. This procedure is explained in the Dynare Forum (see Pfeiffer, 2018).

direct impact on output by hitting the production function. Second, they have a direct effect on the capital accumulation process, which brings about additional persistency. Third, they directly hit banks' balance sheets, by changing the value of assets. Due to their large impact on the model, it is not surprising that they have an important effect on the welfare results. When only technology shocks are present, households are mostly indifferent between country-specific and union-wide rules. Furthermore, in such a world, unconventional measures only have a small impact on welfare. These findings are not surprising, as unconventional monetary policy targets the financial sector, which, in the case of technology shocks, only causes "a modest amplification of the decline in output" (Gertler and Karadi, 2011, p. 26). If households were to exist in a world with only net wealth shocks, i.e., purely financial shocks, they would unambiguously prefer rules based upon country-specific indicators. There are sizeable gains from unconventional monetary policy, even with small optimal coefficients. Credit spread rules score higher than credit growth rules, which implies that the credit spread might be a better indicator of the needs of the financial system than credit growth. In a world with only monetary policy shocks, by construction, households are completely indifferent between country-specific and union-wide rules, as these shocks are not country-specific.

As capital quality shocks were found to drive the main result, it seems natural to have a closer look at the economies' direct response to capital quality shocks. Figures 3.3 and 3.4 show the impulse responses to an adverse 1% capital quality shock in the home economy. While the blue line portrays the case without central bank credit policy, the red line portrays the case with country-specific credit policy and the black dashed line displays the case with union-wide credit policy. In the setup underlying figure 3.3 it is assumed that the central bank reacts to the *credit spread* whereas the impulse responses displayed in figure 3.4 are based on the assumption that the central bank reacts to *credit growth*.

In general, credit policy significantly moderates the contraction in the economy hit by the shock. By taking over some of the lending activities of the troubled banking sector, the central bank succeeds in dampening the rise in the credit spread and the drop in asset prices. This, in turn, dampens the decline in banks' lending activities. In the absence of central bank credit policy, the foreign economy experiences a decline in output which is essentially driven by the deterioration of foreign banks' balance sheets which are exposed to home assets. As explained in chapter 2, given financial market integration, the home capital quality shock directly hits foreign banks' balance sheets by destroying part of the asset portfolio. Credit policy by the central bank can completely eliminate the adverse effect on foreign output (and other real and financial variables) by effectively combatting the balance sheet recession in the foreign economy.

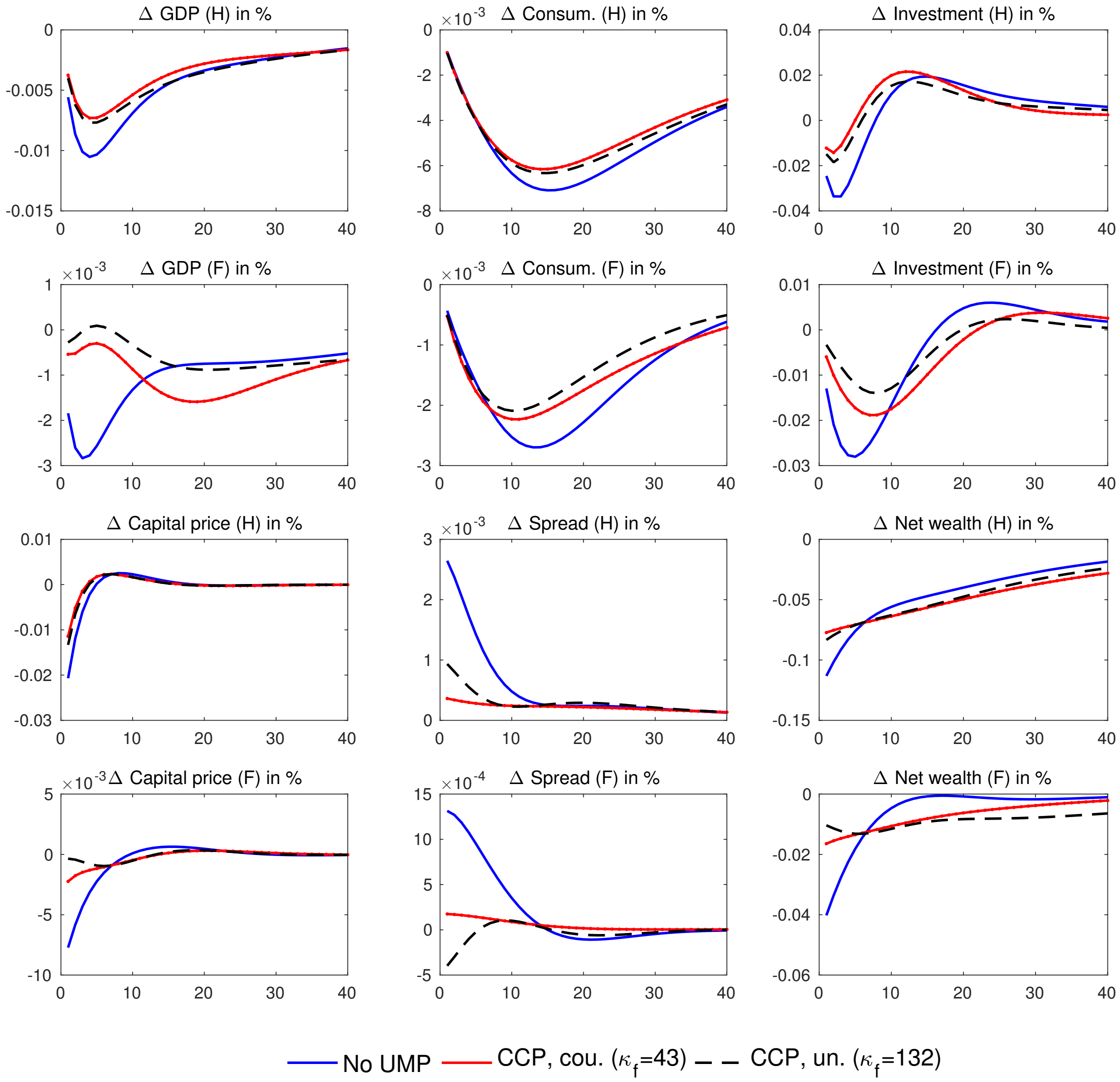

Figure 3.3: *Impulse Responses to an Adverse 1% Capital Quality Shock under a Credit Spread Rule (Rule 1)*

Recall that in the all-shocks environment as well as in the environment only featuring capital quality shocks, union-wide policies yield higher welfare in the case of credit spread rules (figure 3.3), whereas country-specific policies yield higher welfare in the case of credit growth rules (figure 3.4). In order to understand the impulse responses, it is important to remember that when the central banks adheres to a union-wide rule it reacts to union-wide averages and intermediates the same share of funds in both countries. On the other hand, when it follows country-specific rules, the shares of funds provided in each country are chosen based on country-specific needs. Therefore, by construction, in the economy hit by a shock, country-specific policy leads to more stabilization than union-wide policy, while the opposite is true in the economy not hit by the shock.

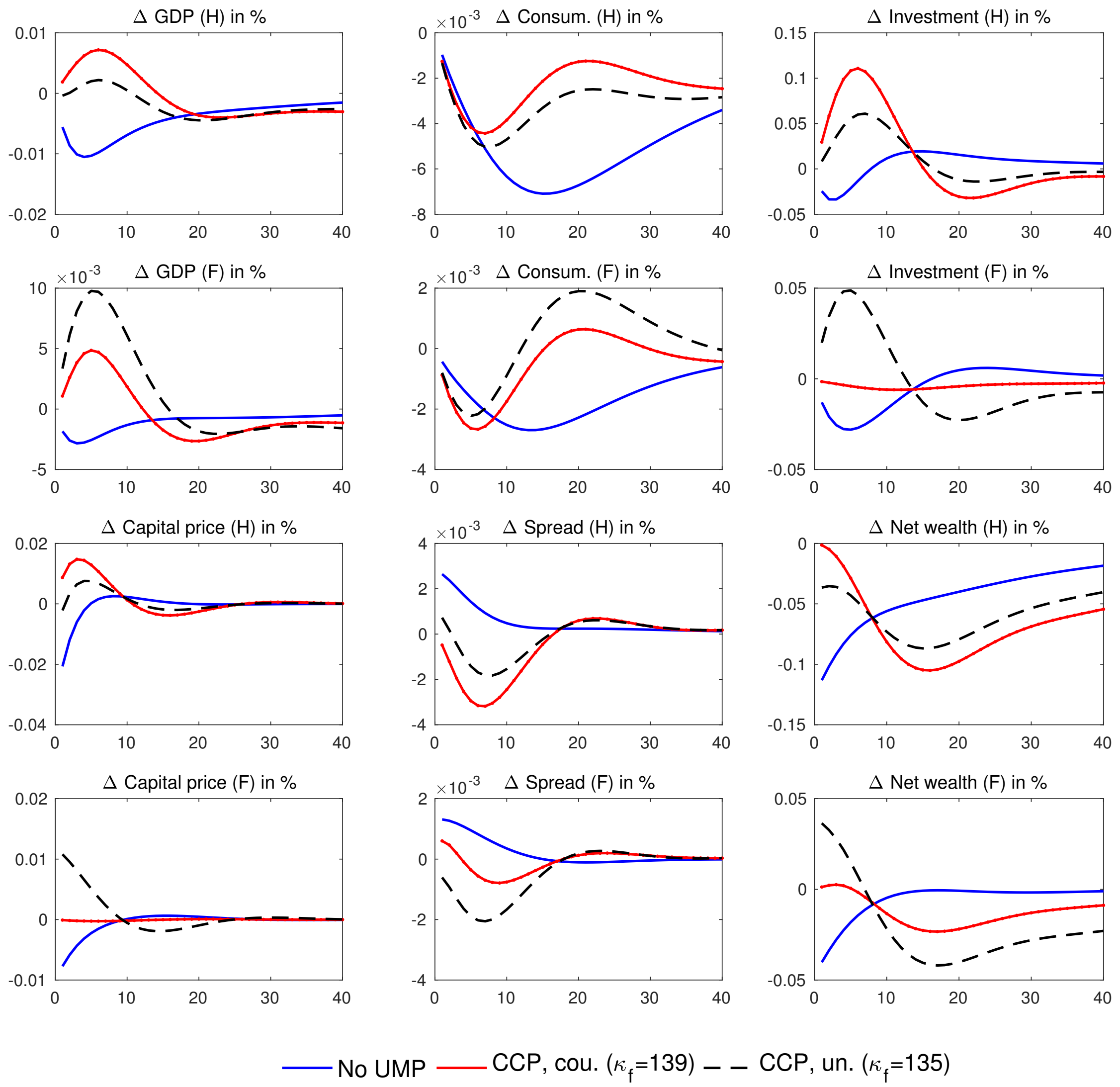

Figure 3.4: *Impulse Responses to an Adverse 1% Capital Quality Shock under a Credit Growth Rule (Rule 2)*

The figures clearly show that the differences between country-specific and union-wide policies are much smaller for credit spread rules (figure 3.3) than for credit growth rules (figure 3.4). This holds even though, in the latter case, the optimal coefficients are much more alike ($\kappa_f = 139$ and $\kappa_f = 135$). When the central bank follows a credit spread rule (figure 3.3), the stabilization provided to the home economy is very similar, regardless of whether the corporate credit purchases are conducted in a union-wide or a country-specific manner. In the foreign economy, per construction, union-wide policy leads to more stabilization than country-specific policy in both figures. However, for credit growth rules (figure 3.4) the differences between union-wide and country-specific policy are much more pronounced. In figure 3.4, we can even observe "overstabilization" for union-wide rules: Foreign investment, net worth and capital prices are pushed into the opposite direction when the monetary authority relies on union-wide as opposed to country-specific indicators. These observations are also reflected in the consumption volatilities reported in table B.1 in the appendix. For corporate credit policy conducted according to a credit spread rule, consumption volatility is lower when the central bank reacts to union-wide indicators as opposed to country-specific indicators (0.0335 versus 0.0342). For corporate credit policy conducted according to a credit growth rule, consumption volatility is lower when the central bank relies on country-specific indicators as opposed to union-wide indicators (0.0270 versus 0.0294). An explanation for these results is that – at least in the case of capital quality shocks – credit spreads are much more correlated across countries than credit growth.

As the cross-country correlations of the indicators of the unconventional monetary policy rules seem to be an important driver of the findings of the impulse response analyses, it seems worthwhile to conduct robustness checks with respect to some of the determinants of the cross-country correlation of the indicator variables. In particular, I analyze the two extreme cases where banks do not provide credit to foreign firms and, on the other extreme, where banks hold a fully diversified portfolio ($\mu_b = 0.5$). Tables B.5 and B.6 in the appendix show the optimal coefficients and welfare results for the different rules in the two extreme cases. Table B.5 shows that with domestic credit provision, the result that credit policy following a credit spread rule yields higher welfare when reacting to union-wide indicators still holds. In the case of fully diversified banks (see table B.6), however, it does not hold any more. Now, union-wide rules yield higher welfare, when the central bank resorts to credit growth as an indicator variable. Tables 3.3 and 3.4, below, support the view that this is again the result of the underlying cross-country correlations: In the baseline model ($\mu_b = 0.91$) and the model with domestic credit provision, the correlation between home and foreign credit spreads is higher than the correlation between home and foreign credit growth. In the model with fully diversified bank portfolios, the ranking is turned around. This result holds for an environment with all shocks, but is even more pronounced when only taking into account capital quality shocks.

Correlation between	Baseline $\mu_b = 0.91$	Domestic credit	Full diversification $\mu_b = 0.5$
Y, Y^*	0.684	0.608	0.786
λ, λ^*	0.697	0.609	0.845
$\frac{R_k}{R}, \frac{R_k^*}{R^*}$	0.908	0.662	0.871
QK, Q^*K^*	0.686	0.498	0.995

Table 3.3: *Cross-Country Correlations*

Correlation between	Baseline $\mu_b = 0.91$	Domestic credit	Full diversification $\mu_b = 0.5$
Y, Y^*	0.457	0.608	0.972
λ, λ^*	0.590	0.609	0.981
$\frac{R_k}{R}, \frac{R_k^*}{R^*}$	0.810	0.662	0.228
QK, Q^*K^*	0.384	0.498	0.987

Table 3.4: *Cross-Country Correlations (Only Capital Quality Shocks)*

Although it is difficult to entirely determine what exactly drives the findings presented in section 3.5.1, it can be concluded that if the central bank reacts to indicator variables which are highly correlated between countries, it might be welfare-superior to resort to union-wide rules as opposed to country-specific rules. If indicators are highly correlated, union-wide rules provide similar stabilization in the economy hit by the shock while overstabilization in the economy spared by the shock is smaller, rendering union-wide rules preferable over country-specific rules. As explained in the introduction, this can be rationalized with the fact that I consider a second-best environment. When financial frictions cannot be fully eliminated, the effects of unconventional monetary policy on welfare are two-fold. On one hand, reductions in volatility reduce the financial accelerator and please the consumption-smoothing motive of the consumer. On the other hand, reductions in volatility might prevent precautionary behavior, such as precautionary saving and capital accumulation. Therefore, depending on the cross-country correlation of the indicator variables, the overall welfare effects can either be higher for rules providing relatively less stabilization in the economy hit by the shock but relatively more stabilization in the other country (=union-wide rules) or for rules providing relatively more stabilization in the economy hit by the shock but relatively less in the other economy (=country-specific rules).

3.5.3 Optimal Simple Rules in an Asymmetric Setup

It is very often argued, that unconventional monetary policy can cause free-riding behavior and lower the incentives to reform financial structures. This is especially relevant in a financially heterogeneous monetary union where the risks and costs of unconventional monetary policy are shared among member countries. In this section, I consider the case where country H has a more sound financial system than country F. This is modeled by introducing a macroprudential instrument with similar effects as a countercyclical capital buffer in country H.[26]

[26] The Basel Committee on Banking Supervision (2017) reports considerable cross-country differences in the implementation of the countercyclical capital buffer required by the Basel III framework.

Regarding the implementation of the capital requirement, I follow Ghilardi and Peiris (2016) and Levine and Lima (2015) by introducing a countercyclical subsidy on net worth, τ_t^N, which adjusts in proportion to variations in the credit-to-GDP-ratio[27]

$$\ln(1+\tau_t^N) = -\kappa_\tau \ln\left(\frac{B_t/Y_t}{B/Y}\right), \tag{3.57}$$

where $\kappa_\tau = 0.1$.

In general, a subsidy on net worth changes the marginal cost of borrowing from households. If implemented in a countercyclical fashion, the subsidy increases whenever the economy performs below average, reducing lending costs, hence, facilitating lending activities, while it precludes the economy from overheating during economic upswings by increasing the cost of borrowing.

Given the subsidy, intermediary i's net worth evolves according to the following equation

$$N_{i,t} = R_t^A B_{i,t-1} - R_{t-1} D_{i,t-1}^B + \tau_{t-1}^N N_{i,t-1}.$$

Solving the banks' maximization problem in the presence of the subsidy, the marginal cost of deposits (formerly given by equation (3.13)) changes to

$$\eta_t = E_t \Omega_{t,t+1}(R_t + \tau_t^N). \tag{3.58}$$

On an aggregate level, only the net worth of existing bankers (formerly given by equation (3.17), or, in the presence of liquidity facilities, by equation (3.34)) is affected by the macroprudential subsidy, i.e.,

$$N_{e,t} = \theta_b \left[(R_t^A - R_{t-1})\phi_{t-1} + R_{t-1} + \tau_{t-1}^N\right] N_{t-1}. \tag{3.59}$$

In this asymmetric setup, the optimal policy coefficients of the country-specific unconventional monetary policy rules will obviously differ between countries, i.e., $\kappa_m \neq \kappa_m^*$ and $\kappa_f \neq \kappa_f^*$ in the country-specific rules. Since I assume that unconventional monetary policy is conducted by a single authority, reaction coefficients κ_m and κ_m^*, or κ_f and κ_f^*, respectively, are chosen to jointly maximize union-wide welfare.

Table 3.5 shows the welfare results for such a heterogeneous monetary union. To facilitate comparisons, column (6) provides the welfare results for the baseline case discussed in section 3.5.1, in which neither country had implemented any financial regulation. First of all, it should be noted that without unconventional monetary

[27] Ghilardi and Peiris (2016) use foreign borrowing as an indicator variable and Levine and Lima (2015) employ a whole set of different indicator variables in the macroprudential rule. However, as it is generally agreed that macroprudential instruments should prevent excessive credit development (see, e.g., Lang and Welz, 2017), the credit-to-GDP-ratio seems to be a natural choice for an indicator variable in a macroprudential rule in the given model.

policy, welfare in the financially more regulated country and average union-wide welfare are higher than in the baseline scenario where both countries are symmetric and macroprudential regulations are absent ($g^H, g^{UN} > g$). Welfare in the financially less regulated economy, however, is slightly lower compared to the baseline case ($g^F < g$), which implies a negative externality of the introduction of macroprudential policy in a single country. A possible explanation for this result is that in the stochastic steady state, the financially regulated country (H) resumes some of the financial activities of the other country. Due to home bias in asset holdings this implies a higher capital stock and, hence, higher consumption in country H at the expense of country F. The latter result changes, once unconventional monetary policy is introduced. In combination with any unconventional monetary policy rule considered, country F also profits from the introduction of macroprudential policy in country H.

	Home (regulated fin. sector)		Foreign (non-regulated fin. sector)		Union average	Symmetric union (table 3.2)
	κ_f, κ_m (1)	g^H (2)	κ_f, κ_m (3)	g^F (4)	g^{UN} (5)	g (6)
No UMP	-	-3.17	-	-3.76	-3.46	-3.69
Rule 1 - Credit Spread Rule						
LF, cou.	66	-2.45	56	-3.09	-2.77	-3.22
LF, un.	69	-2.44	69	-3.06	-2.75	-3.15
CCP, cou.	330	1.87	185	-1.60	0.13	-2.23
CCP, un.	330	2.93	330	-1.75	0.57	-2.09
Rule 2 - Credit Growth Rule						
LF, cou.	40	0.07	69	2.64	1.35	2.50
LF, un.	63	0.20	63	2.04	1.12	2.28
CCP, cou.	23	1.23	330	3.80	2.51	4.17
CCP, un.	46	0.58	46	2.44	1.50	3.78

No UMP: no unconventional monetary policy. LF: liquidity facilities. CCP: corporate credit policy. Cou.: country-specific. Un.: union-wide. κ_f: optimal feedback coefficient for liquidity facilities. κ_m: optimal feedback coefficient for credit policy. g: welfare gains in consumption equivalents in percent of steady-state consumption.

Table 3.5: *Optimal Simple Rules and Welfare Gains with Structurally Heterogeneous Countries*

A further finding is that, once the common central bank adopts a credit growth rule for the conduct of unconventional policies, the macroprudential regulation in country H ceases to be welfare-improving – from the viewpoint of country H and from the viewpoint of the union as a whole ($g^H, g^{UN} < g$). A possible reason for this result is the way the macroprudential rule in country H is specified: As τ_t^N, the macroprudential policy instrument, reacts to a credit measure, its stabilization effects might partly overlap with those of unconventional policies reacting to credit growth. In the following analysis, only the policy combinations which are welfare-improving from the viewpoint of the union will be considered.

The results might imply that unconventional monetary policy aggravates free-riding behavior on the part of a country with a less stable financial sector. To evaluate whether the incentives to reform financial structures are affected by the introduction of unconventional monetary policy measures, country F's welfare gains from unconventional policy provided in column (4) of table 3.5 have to be compared to its welfare gains in the counterfactual case in which it also adopts a macroprudential policy measure. Note that in this case, the two countries of the union would be perfectly symmetric again.

Table 3.6 shows the welfare gains for country F resulting from different unconventional monetary policy regimes, with and without a reform of the financial sector in country F, respectively, and the difference between the two. As indicated by the positive values in the last column, country F profits from a reform of its own financial sector in the first four regimes considered. However, compared to the case without unconventional monetary policy, incentives to reform are considerably reduced when the central bank provides credit to the banking system or purchases corporate sector assets. For corporate sector credit policy conducted in a union-wide fashion, incentives to reform even cease to exist.

	g^F, no reform (1)	g^F, reform (2)	Relative gain from reform (2)-(1)
No UMP	-3.76	-3.19	0.57
Rule 1 - Credit Spread Rule			
LF, cou.	-3.09	-3.06	0.03
LF, un.	-3.06	-3.05	0.01
CCP, cou.	-1.60	-1.51	0.09
CCP, un.	-1.75	-1.75	0.00

No UMP: no unconventional monetary policy. LF: liquidity facilities. CCP: corporate credit policy. Cou.: country-specific. Un.: union-wide. κ_f: optimal feedback coefficient for liquidity facilities. κ_m: optimal feedback coefficient for credit policy. g: welfare gains in consumption equivalents in percent of steady-state consumption.

Table 3.6: *Incentives to Reform Financial Structures in the Foreign Economy*

The results of this section imply that the introduction of unconventional monetary policy in a structurally heterogeneous monetary union might reduce the incentives to reform financial structures in individual countries. The analysis constitutes a first approach to modeling and analyzing the interplay between unconventional monetary policy and structural heterogeneity in a monetary union. The results cannot be generalized to the wide range of structural asymmetries found in, e.g., the European Union. I plan on deepening the analysis of unconventional monetary policy in a heterogeneous monetary union.

3.6 Conclusion

In recent years, the ECB has adopted a wide array of unconventional monetary policy measures. All of them were decided upon on a centralized level, i.e., responding to union-wide conditions. However, while some (several purchase programs) were made available to recipients in Eurozone countries in a fixed manner, according to their respective country's key, others (e.g., liquidity provision) were provided to recipients flexibly according to specific needs and regardless of nationality. Hence, while the former can be seen as measures addressing union-wide circumstances, the latter allow a tailor-made response to country-specific shocks. This paper analyzes the welfare implication of a small sample of unconventional monetary policy measures and, in particular, distinguishes between country-specific and union-wide approaches. Since the subject of cross-country heterogeneity is an important factor when discussing the risks and benefits of unconventional policies in a monetary union, I also consider the case of a structurally asymmetric monetary union.

The results obtained from these analyses provide some important policy implications for a monetary union. First, I show that from a theoretical point of view, it is not in general welfare-improving to use unconventional instruments to address country-specific shocks. However, union-wide policy can only yield higher welfare than country-specific policy, when the central bank reacts upon indicators which are highly correlated between countries. If – for whatever reason – such indicators are not available (measurement problems, high divergence between countries etc.), union-wide policy can lead to welfare losses relative to country-specific policy. That this is a relevant problem in the European Union is, e.g., found by Macchiarelli et al. (2017, p. 5) who report that "corporates in countries like Italy and Spain, where the banking system is more under pressure, might benefit less from the CSPP [Corporate Sector Purchase Program; note from the author]". It is difficult to imagine how some of the unconventional monetary policy instruments, such as corporate sector asset purchases, can be provided in a more targeted (i.e., country-specific) way. However, they could, for example, be accompanied by programs which facilitate access to bond markets and support firms in troubled countries or market segments in meeting the eligibility criteria for bond purchase programs. Second, the analysis of a heterogeneous union showed that unconventional monetary policy – regardless of whether it is conducted in a union-wide or country-specific manner – might lower the incentives to conduct regulatory reforms in single countries. This result supports the case for pushing forward the banking union in order to unify supervision and regulation across countries.

The analysis can be extended in various dimensions. In the given setup, the performance of the different optimal rules should be compared against Ramsey optimal policy. Furthermore, I plan to solve the model under the assumption that the zero-lower bound is binding. This assumption is going to render welfare calculations much more difficult. However, in a first step, it will be interesting to see whether the results of the impulse response and the correlation analyses remain qualitatively the same. An interesting extension to the model, which would, however, go beyond the scope of this paper, is the addition of sovereign bonds to banks' balance sheets and an explicit modeling of government risk. Such a setup would allow the modeling of the so-called "bank-sovereign nexus" and a realistic analysis of a public sector purchase program. Another interesting extension would be to take into account game theoretical issues associated with macroprudential policies being implemented on a national level and unconventional policies being implemented on a union-wide level.

Chapter 4

Endogenous Portfolio Choice by Banks and the International Risk-Sharing Puzzle

Abstract

International consumption risk-sharing is relatively low compared to what theoretical models would predict given the high level of international financial market integration. I show that a model in which leverage-constrained financial intermediaries undertake the international portfolio choice decision instead of households can provide an explanation for this puzzle. The optimal portfolio composition chosen by financial intermediaries does, in general, not induce the highest possible degree of consumption risk-sharing. In particular, financial intermediaries choose to hold too many home assets. This result is driven by an agency problem which causes the motives of bankers and households to diverge. While a direct reduction of the financial friction has a positive impact on international consumption risk-sharing, the introduction of a countercyclical capital buffer does not have the same desirable consequences.

Keywords: International Business Cycles; Financial Frictions; Consumption risk-sharing; Portfolio Choice; Macroprudential Policy
JEL Classification: E44, F30, F44

4.1 Introduction

An important function of international financial markets is to allow individuals to insure themselves against country-specific risk. During the last decades, globalization has been characterized by a striking increase in financial market integration (e.g., Lane and Milesi-Ferretti, 2007). Yet, there is vast evidence, that consumption risk-sharing is modest at best and has increased much less throughout the same period of time (e.g., Kose et al., 2009). Closely related to this international risk-sharing puzzle – the fact that consumption risk-sharing is generally low despite the high level of financial market integration – is the finding of strong and persistent home bias in debt and equity holdings.[1] As foreign assets generally provide better hedging opportunities, standard macro-finance theory predicts much higher international portfolio diversification (e.g., Coeurdacier and Rey, 2012).

This chapter assesses the role of financial intermediaries for international portfolio choice and consumption risk-sharing. To this end, I set up a two-country DSGE model featuring leverage-constrained financial intermediaries modeled as in Gertler and Karadi (2011) and Gertler and Kiyotaki (2011) who hold risky claims on home and foreign capital as in Dedola et al. (2013) and Carniti (2012). It is assumed that the number of states exceeds the number of state-contingent assets traded internationally which, in general, leads to incomplete consumption risk-sharing between countries. In this setup, I also consider the role of macroprudential policy, designed to reduce the adverse effects of financial frictions, for international portfolio choice and consumption risk-sharing.

I find that the assumption that financial intermediaries choose the international portfolio can account for relatively low consumption risk-sharing compared to what could be achieved at the given level of financial market integration. A further interesting finding is that under the assumption that technology shocks are the only driving force behind business cycles, the model can even replicate realistic values of home bias in equity holdings.

These findings can be explained with the presence of a financial friction which drives a wedge between the incentives of households and financial intermediaries – the latter being the agents who choose the international portfolio (see also Maggiori, 2017). Households are primarily concerned about consumption risk. Hence, a portfolio optimally chosen by households coincides with the portfolio which yields the highest possible degree of consumption risk-sharing. As banks are owned by households, they internalize the objectives of households. However, due to an agency problem between bankers and depositors, they have an additional motive, namely the maximization of net wealth which is needed to obtain external funding (Gertler and Karadi, 2011; Gertler and Kiyotaki, 2011). Hence, banks' portfolio choice is motivated not only by their concern about consumption risk but also by their concern about financial risk, the latter consisting in net wealth fluctuations (cf. Maggiori, 2017). Therefore, unless consumption risk and financial risk are perfectly correlated, the chosen portfolio is different from the one which yields the highest possible degree of consumption risk-sharing. In particular, for positive correlations between consumption risk and financial risk, banks prefer

[1] Sorensen et al. (2007) refer to home bias and international risk-sharing as "twin puzzles separated at birth".

a more balanced portfolio than what would yield highest possible consumption risk-sharing. This minimizes the risk of large shocks to the aggregate net wealth of the banking system.

It is further shown, that reducing the financial friction directly induces financial intermediaries to hold more foreign assets which has a positive impact on international consumption risk-sharing. However, reducing the effects of the financial friction on the real economy through the introduction of a countercyclical capital buffer does not have the same desirable consequences for international consumption risk-sharing.

The analyses conducted in this chapter contribute to the literature on international consumption risk-sharing as well as to the literature on international portfolio choice. In most endogenous portfolio choice models,[2] households undertake the portfolio decision, which – as explained above – results in a portfolio composition which maximizes international consumption risk-sharing.[3] And, as Kollmann (2012, p. 567) points out, this usually results in a “surprising amount of cross-country risk pooling”, even if the set of internationally traded assets is very small. Hence, these models lack the ability to provide an explanation to the international risk-sharing puzzle. Dedola et al. (2013) and Carniti (2012) set up models in which leverage-constrained financial intermediaries á la Gertler and Karadi (2011) and Gertler and Kiyotaki (2011) choose the international portfolio. However, they do not analyze the implications of this feature for international risk-sharing in more detail. Maggiori (2017) uses a very similar setup of the banking system, with banks choosing the international portfolio, and shows that the existence of financial frictions, which introduce an additional motive for bankers, can account for several empirical findings related to risk-sharing between financially asymmetric countries. My results are driven by the same mechanism, however, as Maggiori (2017) considers a continuous time endowment model with asymmetric countries, the analyses can be seen as complementary to mine. Finally, Kollmann (2012) considers the role of limited access to financial markets for international consumption risk-sharing. He assumes that international financial markets are complete, but that only a subset of households has access to these markets while the remaining households consume hand-to-mouth. This setup also allows to match certain empirical regularities related to international consumption risk-sharing. To the extent of my knowledge, this study is the first to analyze the role of the size of the financial friction and of macroprudential policy – besides capital controls – for international consumption risk-sharing.

[2]There is a fairly large number of contributions building on the method proposed by Devereux and Sutherland (2007; 2008; 2011a), which is also used here.

[3]In some earlier contributions with financial frictions, so-called *entrepreneurs* choose the international portfolio (Devereux and Yetman, 2010; Dedola and Lombardo, 2012; Yao, 2012). However, as these agents are modeled as a type of household they also choose a portfolio which minimizes consumption risk.

This chapter is organized as follows. The next section presents the model. Section 4.3 explains the calibration and section 4.4 the solution method. In section 4.5, I present and discuss the results. The final section concludes and gives an outlook.

4.2 Model

For the analysis, I use the model developed in chapter 2. Therein, I assume that the world consists of two equally sized countries with symmetric structures. There are four types of optimizing agents in each country – households, final goods producers, capital goods producers and banks. Households consume a homogeneous consumption good, produced by final goods producers in both countries. Furthermore, they supply labor to home final goods firms and save in the form of bank deposits. Period utility is separable in consumption and leisure. The final good is produced from domestic labor and capital. Production is subject to country-specific technology and capital quality shocks. Final goods producers purchase physical capital from domestic capital goods producers, whereby capital purchases are financed with home and foreign bank loans. Depreciated capital is resold to domestic capital goods producers. The latter face convex capital adjustment costs in the process of refurbishing depreciated capital and investing into new capital.

The banking sector is modeled as in Gertler and Karadi (2011). The role of financial intermediaries is to transfer funds between households and final goods producers who use the loans to finance investment into physical capital. Intermediaries face an endogenously determined constraint on their leverage ratio, motivated by a simple agency problem which drives a wedge between saving and borrowing rates. The two-country version of the model developed in this thesis features asset market integration, i.e., intermediaries can purchase state-contingent financial claims on final goods producing firms at home and abroad as in Dedola et al. (2013) and Carniti (2012). The integration of asset markets introduces an endogenous portfolio choice problem, as returns to equity are subject to country-specific risk. I solve this problem using the method proposed by Devereux and Sutherland (2007; 2008; 2011a). Furthermore, I assume that deposit markets are integrated. In particular, I introduce international intermediaries into the model, which – according to the needs in the financial system – channel the deposits of households in the two countries to home and foreign banks. Allowing the net foreign asset position to be adjusted via two margins - asset and deposit trade - might imply two unit roots in a first-order approximation of the model (see, e.g., Schmitt-Grohé and Uribe, 2003). Hence, I introduce two stationarity-inducing features, an endogenous discount factor and a debt-elastic interest rate yield on internationally traded deposits. Since the details of the model have been discussed in chapter 2, I turn directly to the equilibrium conditions of the model. For simplicity, only home country equations will be displayed. Foreign variables will be denoted with an asterisk.

4.2.1 Some Equilibrium Equations

The consumption Euler equation reads

$$1 = \beta(C_{A,t}) E_t \Lambda_{t,t+1} R_t, \tag{4.1}$$

with the household's real stochastic discount factor being defined as $\Lambda_{t,t+1} \equiv \frac{\lambda_{t+1}}{\lambda_t}$, where marginal utility of consumption is given by $\lambda_t = C_t^{-1}$. The return on bank deposits, which are equivalent to real riskless one period bonds, is given by R_t. Note that $C_{A,t}$ is aggregate home consumption which enters the household's consumption maximization problem via the endogenous discount factor $\beta(C_{A,t})$, whose functional form is given by

$$\beta(C_{A,t}) \equiv \omega_c (1 + C_{A,t})^{-\eta_c}, \tag{4.2}$$

as in Devereux and Yetman (2010). Parameter η_c drives the elasticity of the discount factor with respect to consumption while ω_c is used to tie down the steady state of the stochastic discount factor to a certain value. Furthermore, it is implicitly assumed, that households provide their deposits to savings banks which – according to the needs in the financial system – channel the funds to home and foreign banks via international intermediaries. International intermediaries charge a small interest-rate premium on the real interest rate, hence, home and foreign deposits rates are only imperfectly correlated. The premium depends on the real net foreign bond position of the respective country (see, e.g., Hjortsoe, 2016)

$$R_t = R_t^* (1 - \omega_d D_{F,t}), \tag{4.3}$$

where $D_{F,t}$ denotes home households' deposits provided to foreign banks which is equivalent to the real net foreign bond position. Note that in the deterministic steady state $D_F = 0$. Parameter ω_d determines the size of the interest-rate premium. Households' optimal labor supply to domestic final goods producers is given by

$$w_t = \chi \frac{L_t^{\phi}}{\lambda_t}, \tag{4.4}$$

where w_t denotes the real wage and L_t hours worked. Parameter χ is the weight of the disutility of labor in the utility function and ϕ is the inverse of the Frisch elasticity of labor supply.

Home financial intermediaries channel deposits from home and foreign households, $D_{H,t}$ and $D_{H,t}^*$, respectively, to home and foreign final goods producers. In addition to obtaining funds from households, banks also raise funds internally by accumulating retained earnings. Hence, the banking sectors' balance sheet reads

$$Q_t S_{H,t} + Q_t^* S_{F,t} = D_t^B + N_t. \tag{4.5}$$

where N_t denotes the banking sectors' net worth. Variables $S_{H,t}$ and $S_{F,t}$ denote home banks' state-contingent claims on future returns of a unit of capital used in final good production in the home and the foreign economy, i.e., claims on $R_{k,t+1}$ and $R^*_{k,t+1}$, respectively. Total deposits at home banks are denoted as $D_t^B \equiv D_{H,t} + D^*_{H,t}$. Note that in the given setup, home banks have to pay the home real deposit rate R_t on all deposits. There is a continuum of banks in the financial intermediation sector. Each period, a fraction $1-\theta_b$ of banks exits the business and pays out retained earnings to the household sector in a lump-sum fashion. The aggregate net worth of those banks who remain in business, $N_{e,t}$, evolves according to the following equation

$$N_{e,t} = \theta_b \left[\left((R_{k,t} - R_{t-1}) - \frac{Q^*_{t-1} S_{F,t-1}}{B_{t-1}} (R_{k,t} - R^*_{k,t}) \right) \phi_{t-1} + R_{t-1} \right] N_{t-1}, \tag{4.6}$$

where $B_t \equiv Q_t S_{H,t} + Q_t^* S_{F,t}$ are aggregate assets and $\phi_t \equiv \frac{B_t}{N_t}$ is the ratio of intermediated assets to net worth, which will be referred to as the leverage ratio. New bankers are provided with start-up funds proportional to last periods' aggregate assets, hence, entering banks' net worth is given by

$$N_{n,t} = \omega_b (Q_{t-1} S_{H,t-1} + Q^*_{t-1} S_{F,t-1}), \tag{4.7}$$

where ω_b is the fraction of assets given to new bankers by households. Aggregate banking sectors' net worth can therefore be expressed as the sum of existing and new banks' net worth

$$N_t = N_{n,t} + N_{e,t}\, \Xi_{N,t}, \tag{4.8}$$

where $\Xi_{N,t}$ denotes an exogenous disturbance to existing bankers' net wealth. To motivate the requirement to build up net worth, a moral hazard problem is assumed: A banker can choose to divert the fraction $0 < \lambda_b < 1$ of available funds. The cost associated with this fraud is that depositors recover the remaining fraction and force the banker into bankruptcy. Therefore, for households to be willing to deposit funds with bank i, the continuation value of bank i, $V_{i,t}$ must be larger than or equal to the value of funds the banker can divert, i.e.,

$$V_{i,t} \geq \lambda_b B_{i,t}. \tag{4.9}$$

Assuming optimizing behavior and symmetric banks in equilibrium, it can be shown, that the marginal values of an additional unit of home and foreign capital, $\nu_{H,t}$ and $\nu_{F,t}$, respectively, and the marginal value of an additional unit of net worth, η_t, are functions of the returns on capital assets and deposits

$$\nu_{H,t} = E_t \Omega_{t,t+1}(R_{k,t+1} - R_t), \tag{4.10}$$

$$\nu_{F,t} = E_t \Omega_{t,t+1}(R^*_{kt+1} - R_t), \tag{4.11}$$

$$\eta_t = E_t \Omega_{t,t+1} R_t. \tag{4.12}$$

A further first-order condition is given by

$$\nu_{H,t} = \nu_{F,t} \equiv \nu_{t+1} \quad \Leftrightarrow \quad E_t \Omega_{t,t+1} R_{k,t+1} = E_t \Omega_{t,t+1} R^*_{k,t+1}, \tag{4.13}$$

which is the first-order condition relevant for international portfolio choice as will be explained further in section 4.4. Variable $\Omega_{t,t+1}$ represents the stochastic discount factor of the bank. It is defined as

$$\Omega_{t,t+1} = \beta(C_{A,t})\Lambda_{t,t+1}\left[(1-\theta_b) + \theta_b\left(\eta_{t+1} + \nu_{t+1}\phi_{t+1}\right)\right]. \tag{4.14}$$

This discount factor is a key variable for the determination of international portfolio positions and the main results of this chapter. Hence, it deserves further elaboration. Note that $\Omega_{t,t+1}$ contains the stochastic discount factor of the household, $\beta(C_{A,t})\Lambda_{t,t+1}$, as banks are owned by households. However, the existence of a financial friction drives a wedge between households' and banks' motives which causes the discount factors to differ. If the banker knew that she was going to exit business in the next period, i.e., $\theta_b = 0$, the stochastic discount factors were the same. In this particular case, bankers were only concerned about consumption risk. If, however, there is a positive probability that the bank continues to exist, $0 < \theta_b < 1$, the banker also cares about banking risk, i.e., fluctuations of net worth. In this case, her intertemporal choices are also influenced by her expectations regarding the future shadow value of net worth, η_{t+1}, and the future shadow value of leveraging up, $\nu_{t+1}\phi_{t+1}$.

The Cobb-Douglas production function of the representative final goods firm is given by

$$Y_t = A_t(\Psi_t K_{t-1})^\alpha L_t^{1-\alpha}, \tag{4.15}$$

where Y_t denotes output, A_t exogenous technology and Ψ_t exogenous capital quality. Parameter α determines the output elasticity of capital. Capital K_{t-1} was bought from capital goods producers in the same country in the previous period at price Q_{t-1}. The law of motion for capital is given by

$$K_t = I_t + (1-\delta)\Psi_t K_{t-1}, \tag{4.16}$$

where I_t is aggregate investment and δ denotes physical depreciation. Solving the final goods producer's profit maximization problem yields the ex post return to capital

$$R_{k,t+1} = \frac{\alpha \frac{Y_{t+1}}{K_t} + (1-\delta)\Psi_{t+1}Q_{t+1}}{Q_t}, \tag{4.17}$$

and the optimal labor demand of the firm

$$w_t = (1-\alpha)\frac{Y_t}{L_t}. \tag{4.18}$$

Capital goods producers choose the optimal level of investment in the presence of convex capital adjustment costs whose functional form is given by

$$f(\cdot) = \frac{\eta_I}{2}\left(\frac{I_t}{\delta K_{t-1}} - 1\right)^2 \frac{\delta K_{t-1}}{I_t}, \tag{4.19}$$

as in Dedola et al. (2013). Parameter η_I denotes the inverse elasticity of investment with respect to the price of capital. Given optimal behavior, the real price of one unit of capital is given by

$$Q_t = 1 + \eta_I \left(\frac{I_t}{\delta K_{t-1}} - 1\right). \tag{4.20}$$

Finally, the capital market clearing condition states that in each country, the current value of total installed capital has to be equal to the total value of state-contingent claims on future returns of capital

$$Q_t K_t = Q_t(S_{H,t} + S^*_{H,t}). \tag{4.21}$$

Final goods market clearing is given by

$$Y_t + Y_t^* = C_t + C_t^* + [1+f(\cdot)]I_t + [1+f^*(\cdot)]I_t^*. \tag{4.22}$$

The home aggregate resource constraint is derived from aggregation of the budget constraints over home households, considering profits from the ownership of firms, retained earnings from exiting bankers and transfers to new bankers

$$\begin{aligned} Y_t + Q^*_{t-1}S_{F,t-1}R^*_{k,t-1} - Q_{t-1}S^*_{H,t-1}R_{k,t-1} + D_{F,t-1}R_{t-1} + 0.5\pi_t^{IFI} \\ = C_t + [1+f(\cdot)]I_t + Q_t^* S_{F,t} - Q_t S^*_{H,t} + D_{F,t}, \end{aligned} \tag{4.23}$$

where $\pi_t^{IFI} = (R_t^* - R_t)D_{F,t}$ are profits from international financial intermediaries which are equally split between countries.

The full set of equilibrium conditions of the model can be found in the appendix (section A.2.1 of appendix A).

4.3 Calibration

Parameter	Description	Value	Source
Households			
ϕ	inverse of Frisch elasticity	0.276	Gertler and Karadi (2011)
χ	utility weight of labor	3.404	
η_c	parameter from discount factor	0.010	Devereux and Sutherland (2009)
ω_c	parameter capturing steady-state savings propensity	0.996	
ω_d	yield sensitivity to debt	0.010	Hjortsoe (2016)
Capital goods firms			
η_I	inverse elasticity of investment with respect to price of capital	1.728	Gertler and Karadi (2011)
Final goods firms			
α	output elasticity of capital	0.330	Gertler and Karadi (2011)
δ	depreciation rate	0.025	Gertler and Karadi (2011)
Financial intermediaries			
λ_b	fraction of divertable assets	0.486	
ω_b	transfer to entering banks	0.003	
θ_b	quarterly survival rate of banks	0.960	
Exogenous processes			
ρ_ψ	persistence of capital quality shock	0.66	Gertler and Karadi (2011)
ρ_A	persistence of technology shock	0.95	Gertler and Karadi (2011)
ρ_N	persistence of net wealth shock	0.66	
σ_ψ, σ_A, σ_N	standard deviation of shocks	0.01	

Table 4.1: *Parameters*

Table 4.1 reports the baseline calibration and its sources. The time unit is one quarter. Most parameters are quite standard and do not need to be discussed.

The weight of labor in the utility function was chosen such that the household devotes one third of her time to work.

Regarding the banking sector parameters, in this chapter, I deviate from the calibration proposed by Gertler and Karadi (2011). In particular, I set θ_b to match an average lifetime of a bank of 6.25 years. The reason is that this parameter choice allows me to hold the parameter constant throughout the experiments conducted in section 4.5.2.[4] The other two banking sector parameters, λ_b, the divertable fraction of assets and ω_b, the transfer to entering bankers, where jointly chosen to match a

[4]A θ_b of 0.972 would render the fraction of divertable assets very high ($> 70\%$) if combined with the higher credit spread. Furthermore, parameter ω_b turns negative if $\theta_b = 0.972$ is combined with a steady-state leverage ratio of four and an interest rate spread of 200 basis points.

steady-state leverage ratio of four, as in Gertler and Karadi (2011) and Gertler and Kiyotaki (2011), and a steady-state interest rate spread of 200 basis points. The latter is higher than the pre-crisis spread reported in Gertler and Karadi (2011) and Gertler and Kiyotaki (2011) but lies between the values reported by Fiore and Uhlig (2011) (170 basis points) and Živanović (2017) (258 basis points) for the US. In section 4.5.2, I analyze the implications of varying the banking sector parameters.[5]

Parameter η_c in the endogenous discount factor was taken from Devereux and Sutherland (2009). In general, it should be noted that this parameter can have considerable implications for steady-state portfolio choice and risk-sharing. Hence, it should be set to a small value. However, choosing it to be too small induces a unit root in a first-order approximation of the model. Given $\eta_c = 0.01$ and the steady-state value of consumption, parameter ω_c was chosen as to guarantee an annual steady-state interest rate of 4%, i.e., a steady-state value of $\beta(C_A)$ of 0.99.

The three exogenous variables A_t, Ψ_t and $\Xi_{N,t}$ are assumed to follow AR(1) processes. Persistency and standard deviation of the technology shock are taken from Gertler and Karadi (2011). The persistency of the net wealth shock is set to 0.66 which is equal to the persistency of the capital quality shock. The reason is that the capital quality shock, as well as the net wealth shock directly affect stock variables and, hence, feature a high endogenous persistency. The size of the capital quality shock is set equal to the standard deviation of the other shocks.

4.4 Portfolio Indeterminacy and Solution Method

Recall home banks' first-order condition for international portfolio choice

$$E_t \Omega_{t,t+1} R_{k,t+1} = E_t \Omega_{t,t+1} R^*_{kt+1}. \tag{4.13}$$

Evaluated in the non-stochastic steady state, this equation reads

$$R_k = R^*_k,$$

and, approximated up to first order,

$$E_t R_{k,t+1} \approx E_t R^*_{k,t+1}.$$

[5] The value of 49% for the fraction of divertable assets is – admittedly – quite high. However, this can be justified with the fact that this parameter does not have a direct empirical counterpart but is used to calibrate the steady-state interest rate spread and leverage ratio to resemble realistic values.

Hence, in the steady state and in expectations evaluated up to first-order, both assets pay the same return. This implies that all possible compositions of banks' asset portfolios, given by $B_t = Q_t S_{H,t} + Q_t^* S_{F,t}$, yield the same expected return, i.e., international portfolio choice is indeterminate up to first-order accuracy. The economic intuition behind this indeterminacy problem is that the two capital assets are only distinguishable in terms of their risk characteristics which can only be captured with an approximation of second-order or higher (Devereux and Sutherland, 2008).

To overcome the indeterminacy problem, I use the local method proposed by Devereux and Sutherland (2007; 2008; 2011a). Other local and global methods have been proposed by other authors,[6] however, the method developed by Devereux and Sutherland (2007; 2008; 2011a) is particularly appealing as it uses well-known perturbation techniques and can be quite easily incorporated into otherwise standard programs used to solve DSGE models, e.g., Dynare. It is based on the observation that in models of this kind, only steady-state portfolio holding matter for the first-order dynamics of the remaining variables. In a nutshell, this can be shown by rewriting the model in a way that portfolio holdings always appear in a product with future excess returns, i.e., in the form of $S_{F,t}R_{x,t+1}$ and $S_{F,t-1}R_{x,t}$, where excess returns are defined as $R_{x,t} \equiv R_{k,t} - R_{k,t}^*$. Per construction, up to first-order accuracy, $R_{x,t}$ is equivalent to an exogenous, independent mean-zero i.i.d. random variable. Therefore, in a first order-approximation of the model, the terms $S_{F,t}R_{x,t+1}$ and $S_{F,t-1}R_{x,t}$ always reduce to $S_F R_{x,t+1}$ and $S_F R_{x,t}$, respectively, where S_F denotes steady-state portfolio holdings.

Following Devereux and Sutherland (2007; 2008; 2011a), steady-state portfolio holdings can be found using a second-order approximation of the portfolio equations and a first-order approximation of the non-portfolio parts of the model. An approximation of this kind allows to take into account the risk characteristics of the assets. In practice, it is not necessary to actually conduct the second-order approximation of the portfolio parts of the model, as second-order accurate solutions to policy functions can be obtained using purely linear solution methods (see, e.g., Lombardo and Sutherland, 2007). To apply the solution technique, first, the model needs to be rewritten as described in the previous paragraph whereby steady-state portfolio holdings are set equal to zero and $R_{x,t}$ is replaced by ξ_t, an exogenous, independent mean-zero i.i.d. random variable, whenever $R_{x,t}$ appears in a cross-product with portfolio holdings.[7] Now, the model can be solved using any linear approximation

[6] The methods proposed by Tille and van Wincoop (2010) and Evans and Hnatkovska (2005) also employ perturbation around a non-stochastic steady state to find international portfolios while Coeurdacier et al. (2011) and Juillard (2011) propose to find international portfolios by approximating DSGE models around the risky steady state. Brunnermeier and Sannikov (2015) are able to solve a model featuring an international portfolio choice problem by solving it globally using continuous time.

[7] The set of rewritten equilibrium equations can be found in section A.2.2 of appendix A.

method. In a second step, one needs to find the steady-state portfolio holdings which make the first-order condition for portfolio choice, equation (4.13), together with its foreign counterpart,

$$E_t\Omega^*_{t,t+1}R_{k,t+1} = E_t\Omega^*_{t,t+1}R^*_{kt+1}, \tag{4.13*}$$

hold up to second-order. This can be done by combining the variance-covariance matrix of the underlying shocks with certain policy functions obtained in step one,[8] using a formula derived in Devereux and Sutherland (2007; 2008; 2011a).

Alternatively, the second step of the solution method can be replaced by brute force. Combining equation (4.13) with its foreign counterpart, equation (4.13*), yields

$$E_t(\Omega_{t,t+1} - \Omega^*_{t,t+1})R_{x,t+1} = 0. \tag{4.24}$$

According to the latter, the optimal portfolio is the one for which $\mathrm{cov}(\Omega_{t-1,t} - \Omega^*_{t-1,t}, R_{x,t}) = 0$. Hence, solving the rewritten model repeatedly for different values of steady-state portfolio holdings and extracting the resulting covariances between the difference between $\Omega_{t-1,t} - \Omega^*_{t-1,t}$ and $R_{x,t}$ can also reveal the (locally) optimal steady-state portfolio. Figure 4.1 in section 4.5.1 contains a graphical representation of this method. The vertical blue line in the first plot marks the optimal foreign equity share.

As mentioned in the introduction, in most endogenous portfolio choice models, households undertake the portfolio decision. In this case, the optimal portfolio is the one which solves

$$E_t(\Lambda_{t,t+1} - \Lambda^*_{t,t+1})R_{x,t+1} = 0, \tag{4.25}$$

up to second-order accuracy, where $R_{x,t+1}$ again refers to the excess return of home over foreign assets. It can be a scalar or a vector, depending on the number of traded assets in the particular model. By construction, a portfolio which solves equation (4.25) also maximizes consumption risk-sharing in such a model.

In the present model, described in section 4.2, the stochastic discount factor relevant for international portfolio choice differs from the households' one, i.e., $\Omega_{t,t+1} \neq \Lambda_{t,t+1}$. Hence, there is, generally, no reason to assume that international consumption risk-sharing will be at its optimum. Furthermore, in the given framework the particular portfolio which maximizes international consumption risk-sharing is not the one which solves equation (4.25). The reason is, that in my model, households do not have direct access to the state-contingent returns of the assets. Hence, a portfolio which renders the difference in households' stochastic discount factors orthogonal to the excess return on home assets does not have any economic meaning in the framework considered here.

[8]In particular, one needs to obtain the policy functions of $\Omega_{t-1,t} - \Omega^*_{t-1,t}$ and of $R_{k,t} - R^*_{k,t}$ in reaction to all shocks, including ξ_t.

The next section will present and discuss the results. To obtain readily interpretable results on international portfolio holdings, I define portfolio holdings as the share of foreign capital holdings in home banks' portfolios, which – due to symmetry – is equal to the share of home capital holdings in foreign banks' portfolios, i.e.,

$$\gamma_t \equiv \frac{Q_t^* S_{F,t}}{Q_t^* S_{F,t} + Q_t S_{H,t}} = \frac{Q_t S_{H,t}^*}{Q_t^* S_{F,t}^* + Q_t S_{H,t}^*}.$$

The steady-state portfolio share optimally chosen by banks, i.e., the one which solves equation (4.24) up to second-order accuracy, is denoted by γ_B. Given the research question, another portfolio share of interest is the one which maximizes consumption risk-sharing. As stated above, in this model, the portfolio which maximizes international consumption risk-sharing is not the one which solves equation (4.25). Instead, I will determine the portfolio share which maximizes the correlation between home and foreign marginal utilities, because in a two-country DSGE model without real exchange rate fluctuations, the correlation between home and foreign marginal utilities reflects the degree of consumption risk-sharing (see, e.g., Nuntramas, 2011). A correlation coefficient of one implies perfect risk-sharing. The risk-sharing maximizing portfolio share is denoted by γ_{RS}.

Last but not least, in some instances, I will report the optimal portfolio share chosen by households for the same model, but with the banking sector removed. In this case, households directly receive the state-contingent returns of the assets. The corresponding portfolio share is denoted by γ_{HH}. Note that γ_{HH} solves equation (4.25).

4.5 Results

In this section, I first present and discuss the optimal steady-state portfolio share chosen by banks and the degree of international consumption risk-sharing associated with it. In subsection 4.5.2, I consider the effects of changing the size of the financial friction on the results obtained in 4.5.1. Lastly, in subsection 4.5.3, I analyze whether and how the introduction of macroprudential policy alters the implications of portfolio choice by banks for international consumption risk-sharing.

4.5.1 Steady-State Portfolio Holdings and Implications for Risk-Sharing

Using the baseline calibration, the steady-state foreign equity share amounts to 0.62, i.e., financial intermediaries hold a portfolio with a foreign bias. This result is fairly robust to varying parameter values, except for the calibration of the shock processes, the implications of which are discussed below. Data on international portfolio holdings show that developed countries exhibit an equity home bias of $60-80\%$, i.e., a γ_B of $0.2-0.4$ (see, e.g., Coeurdacier and Rey, 2012). The baseline version of this model cannot replicate this characteristic of international financial markets – a weakness shared by many other two-country models with endogenous portfolio choice. The reason is that risk averse agents prefer assets which promise a high payoff during bad states of the economy. In standard open economy models[9], the class of assets which matches this criterion best is foreign equity. For households, bad states are, in general, states in which labor income is low. The reason is, that when a Cobb-Douglas production function is used, returns on domestic labor and capital are highly correlated (see, e.g., Coeurdacier and Rey, 2012). As bankers are owned by households, the insurance of labor income constitutes at least part of their motive. There are various contributions proposing certain model features which lead to equity home bias in international portfolios by uncoupling the return to home assets from home labor income. Coeurdacier and Rey (2012) provide an excellent review of this literature.[10] As the focus of the present paper is on the role of financial frictions for international portfolio choice and risk-sharing, I refrain from extending the real sector of the model in such ways.

Figure 4.1 depicts different second-order properties of the model for varying degrees of balance sheet exposure. The first graph shows the covariance of the difference between stochastic discount factors of bankers, $\Omega_{t-1,t} - \Omega^*_{t-1,-t}$, and the excess return on capital, $R_{x,t} \equiv R_{k,t} - R^*_{k,t}$. As explained above, the portfolio allocation chosen optimally by banks is the one which satisfies equation (4.24) up to second-order accuracy. Hence, the first graph intersects the x-axis at point 0.62. As it can be seen in the second plot of figure 4.1, the foreign asset share which maximizes consumption risk-sharing, measured as $\text{corr}(\lambda_t, \lambda_t^*)$, is approximately 1.47. Such a portfolio, i.e., $\gamma > 1$, reflects the hypothetical case that home banks go short on home assets, i.e., that they channel funds from home firms to foreign firms. This portfolio is equal to the portfolio which minimizes consumption volatility, depicted in the third graph. Hence, the portfolio chosen by banks yields a lower degree of consumption risk-sharing and higher consumption volatility than what could be achieved in the given model.[11]

[9]With “standard” I refer to RBC models with commonly used shocks such as technology shocks.

[10]Model features which can uncouple domestic labor income from domestic asset return are, for example, sticky prices in combination with real exchange rate fluctuations and international trade in nominal bonds (Engel and Matsumoto, 2009) or capital accumulation together with international trade in capital goods (Coeurdacier et al., 2010).

[11]Considering this, it would be interesting to determine whether the portfolio chosen by banks is welfare-inferior to a portfolio which maximizes risk-sharing and minimizes consumption volatilty. Since consumption volatility is directly related to welfare and many papers have shown the gains of international consumption risk-sharing for welfare (for an overview, see, e.g., van Wincoop, 1999), it seems likely. However, to obtain a definite answer to this question it would be necessary to conduct a full-fletched welfare analysis. The solution method as explained in section 4.4 can, of course, only be used to analyze first-order accurate macroeconomic dynamics. Nevertheless, it

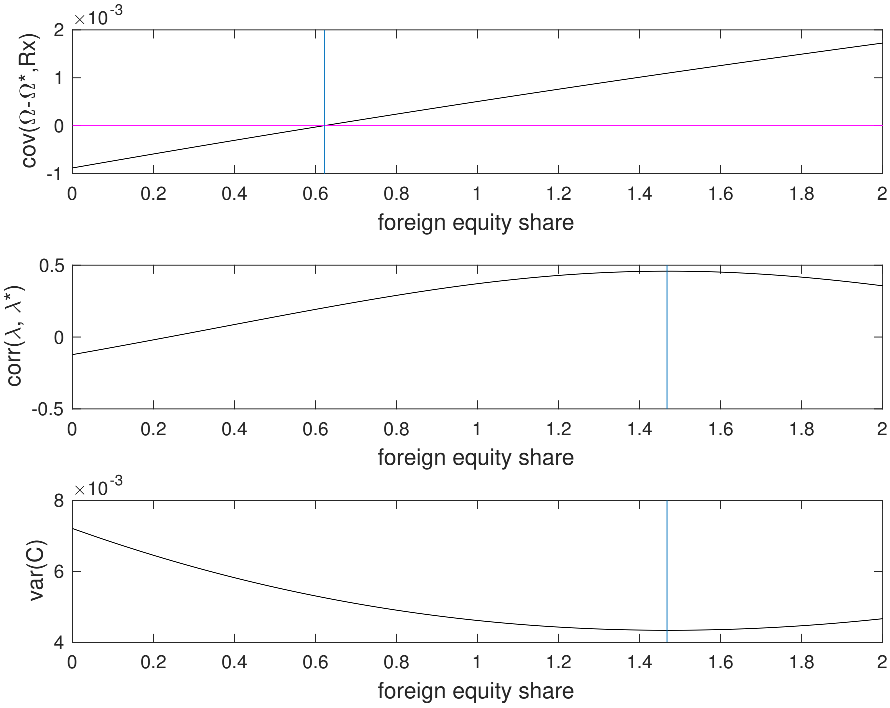

Figure 4.1: *Portfolio Choice and Risk-Sharing*

Why do bankers choose to hold too many home assets relative to what households would prefer? The intuition for this result is as follows. Risk averse households prefer to smooth their consumption streams. This generates a demand for assets which promise a high payoff during bad states of the economy, which are usually foreign assets. As mentioned above, various model features have been proposed to uncouple the return to home equity from home labor income such that home agents are inclined to hold a higher share of domestic assets. My model does not include such features, which explains why foreign equity holdings must be high to provide for optimal hedging of labor income risk and, hence, for optimal consumption risk-sharing. Bankers inherit the preference for consumption smoothing from households, however, this only explains one part of their motive. Additionally, they care about the growth of their net worth which is generated through excess returns over the risk-free rate. However, expected excess returns from home and foreign asset holdings are equalized in expectations in this kind of model. Therefore, generally, bankers cannot hedge their country-specific banking risk by holding a portfolio which exhibits a large bias towards a certain class of assets. In addition, bank's balance sheets are subject to multiplier effects. Hence, bankers prefer smaller shocks

is straightforward to take the method to a higher order of approximation, as shown in Devereux and Sutherland (2008; 2011a), which then allows to conduct a second-order approximation of the model. Unfortunately, however, a welfare analysis based on this method seems to deliver spurious welfare results when the particular model features large inefficiencies.

to their balance sheet which also generates a motive to hold a rather diversified (i.e., $\gamma_B \approx 0.5$) portfolio.

As is well known and also supported by the results obtained in chapter 2, international business-cycle correlations and, hence, risk-sharing properties of internationally traded assets, strongly depend on the underlying sources of risk. Therefore, to obtain a better understanding of the mechanisms driving the results, it seems recommendable to look at the optimal portfolio holdings for different shock structures. Table 4.2 provides figures on the optimal portfolio chosen by bankers, γ_B, the risk-sharing maximizing portfolio, γ_{RS}, the actual risk-sharing obtained in the model, i.e., corr(λ_t, λ_t^*) at γ_B, the highest possible risk-sharing in the model, i.e., corr(λ_t, λ_t^*) at γ_{RS}, the difference between the latter two and the correlation between the bankers' and the households' stochastic discount factors. The figures are reported for the baseline model (all shocks) and for versions of the model which feature only one type of shock each.

	γ_B in % (1)	γ_{RS} % (2)	Actual risk-sharing (3)	Potential risk-sharing (4)	Difference (4)-(3) (5)	corr(Ω, Λ) (6)
Baseline	62	147	0.20	0.46	0.26	0.40
Only ϵ_t^Ψ	64	150	0.20	0.49	0.29	0.81
Only ϵ_t^A	41	125	0.25	0.44	0.18	0.49
Only ϵ_t^N	496	414	-0.72	-0.69	0.03	-0.02

Risk-sharing is measured as corr(λ, λ^*).

Table 4.2: *Portfolio Choice and Risk-Sharing for Different Shock Structures*

First of all, it should be emphasized, that the optimal portfolio shares obtained are very sensitive to the calibration of the shock processes.[12] Hence, not to much emphasis should be placed on the actual portfolio shares obtained. Nevertheless, it is interesting to note, that the model exhibits home bias in equity holdings if only technology shocks exist (Only ϵ_t^A), even though, for this kind of shock, foreign capital assets provide a very good hedge for home labor income fluctuations. The fact that the portfolio is biased towards home assets might be explained with the relatively low correlation between $\Omega_{t-1,t}$ and $\Lambda_{t-1,t}$ compared to the scenario with only capital quality shocks. The different correlations might be explained with the fact that technology shocks mostly affect the real side of the economy and do not provoke large financial acceleration effects compared to capital quality shocks (cf. Gertler and Karadi, 2011). Table C.2 in the appendix shows the international portfolios which would be chosen by households if the banking sector were absent (γ_{HH}). It can be seen that households prefer similar portfolios in the presence

[12]E.g., increasing the persistency of the technology shock from 0.95 to 0.975 leads to $\gamma_B > 0.5$, i.e., a foreign biased portfolio.

of capital quality shocks and in the presence of technology shocks. Hence, the comparatively low γ_B in the scenario in which only technology are present seems to be driven by the fact that financial intermediaries undertake the international portfolio decision in my model and that they are less affected by technology shocks than households.

With respect to the risk-sharing implications of international portfolio choice by banks, table 4.2 shows that actual consumption risk-sharing is always below potential. As stated above, this can be explained with the fact that households' and bankers' motives deviate from each other which manifests itself in the less than perfect correlation of stochastic discount factors, i.e., corr$(\Omega_{t-1,t}, \Lambda_{t-1,t})< 1$, as shown in column (6).

Furthermore, table 4.2 shows that when the correlation between the stochastic discount factors is positive – meaning that the motives overlap to some extent – the banker chooses a portfolio smaller than the one which maximizes international consumption risk-sharing as has been explained above. The figures in the last row reflect a world in which only shocks to the net wealth of bankers exist. In this case, households' and bankers motives are almost uncorrelated as the effects of the net wealth shock – a purely financial shock – on the real economy are quite small which has been already observed in chapter 2. The latter implies that varying the portfolio does not have large effects on the real economy which can also explain the small difference between actual and potential risk-sharing.

A further interesting implication of figures provided in table 4.2 is that in the given model, even if the number of shocks corresponds to the number of state-contingent securities, potential consumption risk-sharing is far from being perfect. This deviates from what generally prevails in a model in which households undertake the portfolio choice decision. It seems likely that this is also driven by the existence of the financial friction.

To conclude, the assumption that bankers choose the international portfolio has important implications for international portfolio choice and consumption risk-sharing. Therefore, in the next section it is analyzed in how far the effects on international portfolio choice and risk-sharing depend on the size of the financial friction.

4.5.2 Size of the Financial Friction

The parameters governing the financial friction in this model are the divertable fraction of assets, λ_b, the average lifetime of banks, θ_b, and the transfer to entering bankers, ω_b. Each parameter taken by itself has only little economic meaning, however, jointly they determine the steady-state interest rate spread and the steady-state leverage ratio which have empirical counterparts. It should be noted that varying only one of the parameters into a certain direction, not necessarily increases or decreases the financial friction monotonically, in the sense that steady-state spread and leverage ratio are pushed into the same direction. Therefore, I analyze the effects of the size of the financial friction on international risk-sharing by comparing the baseline scenario to three scenarios in which either a lower spread, a lower leverage ratio or a lower spread and a lower leverage ratio prevail.

Table 4.3 sums up the effects of the parameter choices on the steady-state values of the leverage ratio and the interest rate spread. In the "Lower spread" scenarios, λ_b and ω_b are chosen to ensure a steady-state interest rate spread of 100 basis points which Gertler and Karadi (2011, p. 25) report as the pre-crisis spread "between mortgage rates and government bonds and between BAA corporate versus government bonds". In the "Lower leverage" scenarios, the parameters are chosen to ensure a steady leverage ratio of three, which corresponds to the binding minimum requirement in the European Union from 2018 onwards.

		Baseline	Lower spread	Lower leverage	Lower spread & leverage
Parameter setting:					
divertable assets	λ_b	0.486	0.331	0.526	0.409
transfer to new banks	ω_b	0.003	0.005	0.005	0.008
quarterly survival rate	θ_b	0.96	0.96	0.96	0.96
Steady state target:					
leverage ratio	$\frac{QS_H+Q^*S_F}{N}$	4	4	**3**	**3**
interest rate spread (p.a.)	$4\ln\frac{R_k}{R}$	0.020	**0.010**	0.020	**0.010**

Table 4.3: *Banking Sector Parameters*

Table 4.4 shows how the size of the financial friction affects portfolio choice and consumption risk-sharing. First, it should be noted that γ_B, the foreign equity share chosen by banks, increases and moves closer to the risk-sharing maximizing foreign equity share when the financial friction becomes smaller. This is in line with the intuition given in section 4.5.1: When the financial friction decreases, insuring against fluctuations in net wealth becomes relatively less important for international portfolio choice. As table C.1 in the appendix shows, if only capital quality or technology shocks are present, this is also reflected in a higher correlation between the stochastic discount factors, i.e., an increase in $\text{corr}(\Omega_{t-1,t}, \Lambda_{t-1,t})$. As table C.1 in the appendix also shows, portfolio choice and risk-sharing associated with net wealth shocks, i.e., purely financial shocks are not significantly altered by the reduction of the financial friction. Second, driven by the reduction of the distance between γ_B and γ_{RS}, the gap between actual and potential risk-sharing is reduced and, through the increase in γ_B, actual consumption risk-sharing increases. What is not obvious at first sight is why the reduction of the financial friction reduces γ_{RS} and potential risk-sharing. A shown in table C.2 in the appendix, in the same model, but without a banking sector, a household would choose a portfolio with a very large foreign bias and risk-sharing would be close to perfect. This implies that whenever a financial friction exists, an decrease in the financial friction generally decreases the risk-sharing potential of foreign assets.

	γ_B in % (1)	γ_{RS} % (2)	Actual risk-sharing (3)	Potential risk-sharing (4)	Difference (4)-(3) (5)	corr(Ω, Λ) (6)
Baseline	62	147	0.20	0.46	0.26	0.40
Lower spread	68	118	0.24	0.35	0.11	0.45
Lower leverage	78	132	0.27	0.41	0.14	0.34
Both lower	85	113	0.28	0.32	0.04	0.37

Risk-sharing is measured as corr(λ, λ^*).

Table 4.4: *Portfolio Choice and Risk-Sharing for Different Degrees of Financial Frictions*

To sum up, in the previous section it was shown that the existence of a financial friction and the fact that financial intermediaries choose the foreign equity position significantly reduce the degree of international consumption risk-sharing. Generally, financial intermediaries choose to hold too many home assets. The analyses provided in this section showed that a direct reduction of the financial friction brings the foreign equity position closer to the one which yields the highest possible degree of consumption risk-sharing in the given model. An obvious next step is to consider the effects of macroprudential policy – designed to reduce the amplification of shocks in the financial sector – on portfolio choice and international risk-sharing.

4.5.3 Macroprudential Policy

Macroprudential policy is modeled by introducing an instrument with similar effects as a countercyclical capital buffer. Regarding the implementation of the capital requirement, I follow Ghilardi and Peiris (2016) and Levine and Lima (2015) by introducing a countercyclical subsidy on net worth, τ_t^N, which adjusts in proportion to variations in the credit-to-GDP-ratio[13]

$$\ln(1 + \tau_t^N) = -\kappa_\tau \ln\left(\frac{B_t/Y_t}{B/Y}\right), \tag{4.26}$$

[13]Ghilardi and Peiris (2016) use foreign borrowing as an indicator variable and Levine and Lima (2015) employ a whole set of different indicator variables in the macroprudential rule. However, as it is generally agreed that macroprudential instruments should prevent excessive credit development (see, e.g., Lang and Welz, 2017), the credit-to-GDP-ratio seems to be a natural choice for an indicator variable in a macroprudential rule in the given model.

where $\kappa_\tau = 0.1$ and Y and B denote the steady-state values of output and banks' assets, respectively.

In general, a subsidy on net worth changes the marginal cost of borrowing from households. If implemented in a countercyclical fashion, the subsidy increases whenever the economy performs below average, reducing lending costs, hence, facilitating lending activities while it precludes the economy from overheating during economic upswings by increasing the cost of borrowing.

Solving the banks' maximization problem in the presence of the subsidy, the marginal gain from net wealth (formerly given by equation (4.12)) changes to

$$\eta_t = E_t \Omega_{t,t+1} (R_t + \tau_t^N). \tag{4.27}$$

On an aggregate level, only the net wealth of existing bankers (formerly given by equation 4.6) is affected by the macroprudential subsidy, i.e.,

$$N_{e,t} = \theta_b \left[\left((R_{k,t} - R_{t-1}) - \frac{Q_{t-1}^* S_{F,t-1}}{B_{t-1}} (R_{k,t} - R_{k,t}^*) \right) \phi_{t-1} + R_{t-1} + \tau_{t-1}^N \right] N_{t-1}. \tag{4.28}$$

Table 4.5 shows the effects of introducing a subsidy on net worth on portfolio choice and consumption risk-sharing.[14] As the results differ for each shock, the table provides the results for different shock structures. Note that scenario in which only net wealth shocks are present is omitted as the combination of only these shocks together with a subsidy on the same variable leads to spurious results. The figures contained in table 4.5 show that the introduction of a macroprudential instrument designed to reduce the effects of a financial friction on the real economy does not have the same implications on portfolio choice and risk-sharing as decreasing the financial friction itself. In the baseline scenario and in the scenario with only capital quality shocks, the difference between actual and potential risk-sharing is reduced through the implementation of the macroprudential instrument. However, actual risk-sharing decreases. Furthermore, the foreign equity share chosen by banks becomes smaller. The opposite is true for technology shocks. Here, γ_B and actual risk-sharing increase. However, the gap between actual and potential risk-sharing becomes significantly larger.

A possible explanation for these results is the following. While only capital quality shocks have a direct affect on banks' balance sheets, the direct effects of capital quality shocks and technology shocks on the real economy are similar (see chapter 2 for a more detailed explanation). This explains why $\text{corr}(\Omega_{t-1,t}, \Lambda_{t-1,t})$ is

[14] The results presented in table 4.5 are qualitatively robust to varying the reaction coefficient, κ_τ, within a range of commonly used values, to using the credit spread instead of the credit-to-GDP-ratio as indicator variable in the macroprudential rule, and to using a different instrument, which has also been used in this kind of model – a countercyclical tax on loans (see, e.g., Levine and Lima, 2015).

generally higher in the presence of only capital quality shocks than in the presence of only technology shocks. The way macroprudential policy is modeled here, it provides an insurance mechanism for the financial sector.[15] Whenever the financial sector is in a bad state it receives a subsidy and vice versa. Hence, the effects of shocks on the financial sector are alleviated. This can explain, why in the scenario with only capital quality shocks the correlation between the motives of bankers and households, corr$(\Omega_{t-1,t}, \Lambda_{t-1,t})$, is significantly reduced while it is only marginally affected in the scenario with only technology shocks. The insurance provided to the banking system by the macroprudential instrument might also be the reason why potential consumption risk-sharing becomes very high for technology shocks (0.94). When repercussions in the financial sector are largely insured against by macroprudential policy, the international portfolio could be used to primarily insure against real sector repercussions, i.e., consumption fluctuations. For this it would have to be quite high ($\gamma_{RS} = 2.17$), i.e., closer to the portfolio which would prevail in a world without financial frictions.

	γ_B in % (1)	γ_{RS} % (2)	Actual risk-sharing (3)	Potential risk-sharing (4)	Difference (4)-(3) (5)	corr(Ω, Λ) (6)
Baseline						
No macropru.	62	147	0.20	0.46	0.26	0.40
Macropru.	51	157	0.14	0.35	0.21	0.39
Only Capital Quality Shocks (ϵ_t^{Ψ})						
No macropru.	64	150	0.20	0.49	0.29	0.81
Macropru.	51	147	0.11	0.28	0.17	0.61
Only Technology Shocks (ϵ_t^{A})						
No macropru.	41	125	0.25	0.44	0.18	0.49
Macropru.	51	217	0.26	0.94	0.68	0.50

Table 4.5: *Portfolio Choice and Risk-Sharing with Macroprudential Policy*

To conclude, introducing macroprudential policy, designed to reduce the effects of financial frictions on the real economy, does not have the same effects on international portfolio choice and consumption risk-sharing as reducing the financial friction directly. In particular, while the latter generally induces financial intermediaries to hold more foreign assets which has a positive impact on international consumption risk-sharing, this cannot be achieved through macroprudential policy, the way it is modeled here. The reason is that the subsidy on net worth provides an insurance mechanism to the financial sector which further increases the wedge between the motives of bankers and households, especially if uncertainty is driven by shocks with a large impact on the financial sector, i.e., capital quality shocks.

[15] This also applies to a countercyclical tax on loans, another instrument which has been used in this kind of model.

4.6 Conclusion

It is shown that the presence of leveraged financial intermediaries, choosing the international equity portfolio instead of households, can explain relatively low consumption risk-sharing compared to what could be achieved at the given level of financial market integration. In particular, financial intermediaries choose to hold too many home assets. Furthermore, under the assumption that technology shocks are the only driving force behind business cycles, the model can replicate realistic values of home bias in equity holdings. Considering that in the real world the largest part of portfolio holdings is intermediated by funds (Coeurdacier and Rey, 2012), these results help reconcile theory with empirical evidence on relatively low foreign asset holdings and modest degrees of international consumption risk-sharing despite open financial markets (see, e.g., Kose et al., 2009).

In view of this, it is natural to ask whether policy can improve international consumption risk-sharing, i.e., bring the outcome closer to what would prevail in a world without financial frictions. It was shown that reducing the financial friction directly induces financial intermediaries to hold more foreign assets which has a positive impact on international consumption risk-sharing. However, reducing the effects of the financial friction on the real economy through the introduction of a countercyclical capital buffer does not have the same desirable consequences for international consumption risk-sharing. The latter result should, however, be interpreted with caution as it is not necessarily driven by the nature of a countercyclical capital buffer itself, but by the way it is modeled here, i.e., as a subsidy which provides an insurance mechanism to the financial system. In future work, I plan to consider different ways of modeling macroprudential policy.

This paper is concerned with a key puzzle in international macroeconomics – why international consumption risk-sharing is relatively low compared to what could be achieved given the high level of international financial market integration. It offers an explanation based upon the presence of leverage-constrained financial intermediaries. In order to be able to draw normative implications from the positive results presented here, it is necessary to compute welfare associated with portfolio choice by financial intermediaries. The extension of the solution method used in this paper cannot be used for this, as it seems to deliver spurious welfare results in medium-scale models. Hence, it is left for further research to determine the welfare effects of portfolio choice by financial intermediaries using a different solution method.

A further open road for future research is the inclusion of additional shocks such as preference shocks (different from financial shocks), e.g., a shock to the discount factor of households. Given that these shocks have a direct effect on international consumption risk-sharing, it will be interesting to see in how far the motives of households and banks differ in the presence of such shocks.

Appendix A

Appendix to Chapter 2

A.1 Banks' Optimization Problem

Representative bank i chooses home assets, $S_{iH,t}$, foreign assets, $S_{iF,t}$ and deposits $D^B_{i,t}$ to maximize its franchise value, $V_{i,t}$, subject to an incentive constraint, a balance sheet constraint and a law of motion for net worth.

$$\max_{\{S_{iH,t}\},\{S_{iF,t}\},\{D^B_{i,t}\}} \quad E_t\beta(C_{A,t})\Lambda_{t,t+1}[(1-\theta_b)N_{i,t}+\theta_b V_{i,t+1}]$$

$$\begin{aligned} s.t. \qquad V_{i,t} &\geq \lambda_b(Q_t S_{iH,t}+Q^*_t S_{iF,t}), && \text{(A.1)}\\ Q_t S_{iH,t}+Q^*_t S_{iF,t} &= D^B_{i,t}+N_{i,t}, && \text{(A.2)}\\ N_{i,t} &= R_{k,t}Q_{t-1}S_{iH,t-1}+R^*_{k,t}Q^*_{t-1}S_{iF,t-1}-R_{t-1}D^B_{i,t-1}. && \text{(A.3)} \end{aligned}$$

In order to solve the optimization problem of the bank, we guess that the value function is linear in home and foreign assets and net wealth

$$V_{i,t}=\nu_{iH,t}Q_t S_{iH,t}+\nu_{iF,t}Q^*_t S_{iF,t}+\eta_{i,t}N_{i,t}. \tag{A.4}$$

Using this guess and assuming that the incentive constraint binds, the latter can be expressed as

$$\nu_{iH,t}Q_t S_{iH,t}+\nu_{iF,t}Q^*_t S_{iF,t}+\eta_{i,t}N_{i,t}=\lambda_b(Q_t S_{iH,t}+Q^*_t S_{iF,t}). \tag{A.5}$$

The Lagrangian function of the maximization problem can be written as

$$\begin{aligned} \mathcal{L} \;=\;& \nu_{iH,t}Q_t S_{iH,t}+\nu_{iF,t}Q^*_t S_{iF,t}+\eta_{i,t}N_{i,t}\\ &+\lambda\left[\nu_{iH,t}Q_t S_{iH,t}+\nu_{iF,t}Q^*_t S_{iF,t}+\eta_{i,t}N_{i,t}-(\lambda_b(Q_t S_{iH,t}+Q^*_t S_{iF,t}))\right]. \end{aligned}$$

Note that the Lagrangian function contains only one of the three constraints. The remaining two, equations (A.2) and (A.3), will be used later. Given that the incentive constraint binds ($\lambda > 0$), the first-order conditions with respect to $S_{iH,t}$, $S_{iF,t}$ and λ are

$$\begin{aligned}\nu_{iH,t}(1+\lambda) &= \lambda_b\lambda, &(A.6)\\ \nu_{iF,t}(1+\lambda) &= \lambda_b\lambda, &(A.7)\\ (\lambda_b-\nu_{iH,t})Q_tS_{iH,t}+(\lambda_b-\nu_{iF,t})Q_t^*S_{iF,t} &= \eta_{i,t}N_{i,t}. &(A.8)\end{aligned}$$

Note from (A.6) and (A.7) that

$$\nu_{iH,t} = \nu_{iF,t} \equiv \nu_{i,t}. \tag{A.9}$$

Hence, equation (A.8) becomes

$$Q_tS_{iH,t} + Q_t^*S_{iF,t} = \frac{\eta_{i,t}}{\lambda_b - \nu_{i,t}}N_{i,t}. \tag{A.10}$$

Using the guess of the value function, equation (A.4), evaluated in $t+1$, and the results of the the maximization problem, the original value function can be rewritten as

$$\begin{aligned}V_{i,t} =& E_t\beta(C_{A,t})\Lambda_{t,t+1}(1-\theta_b)N_{i,t+1}\\ &+ E_t\beta(C_{A,t})\Lambda_{t,t+1}\left[\theta_b(\nu_{iH,t+1}Q_{t+1}S_{iH,t+1}+\nu_{iF,t+1}Q_{t+1}^*S_{iF,t+1}+\eta_{i,t+1}N_{i,t+1})\right]\\ =& E_t\beta(C_{A,t})\Lambda_{t,t+1}(1-\theta_b)N_{i,t+1}\\ &+ E_t\beta(C_{A,t})\Lambda_{t,t+1}\theta_b(\nu_{i,t+1}(Q_{t+1}S_{iH,t+1}+Q_{t+1}^*S_{iF,t+1})+\eta_{i,t+1}N_{i,t+1}).\end{aligned}$$

Plugging in equation (A.10), the value function can be rewritten exclusively in terms of individual net wealth

$$V_{i,t} = E_t\beta(C_{A,t})\Lambda_{t,t+1}\left(1-\theta_b+\theta_b(\nu_{i,t+1}\tfrac{\eta_{i,t+1}}{\lambda_b-\nu_{i,t+1}}+\eta_{i,t+1})\right)N_{i,t+1}.$$

Using the balance sheet constraint (equation (A.2)), the law of motion for net worth (equation (A.3)) can be rewritten without deposits

$$N_{it} = (R_{k,t}-R_{t-1})Q_{t-1}S_{iH,t-1}+(R_{k,t}^*-R_{t-1})Q_{t-1}^*S_{iF,t-1}+R_{t-1}N_{i,t-1} \tag{A.11}$$

Defining

$$\Omega_{it,t+1} \equiv \beta(C_{A,t})\Lambda_{t,t+1}\left[(1-\theta_b)+\theta_b\left(\eta_{i,t+1}+\nu_{i,t+1}\frac{\eta_{i,t+1}}{\lambda_b-\nu_{i,t+1}}\right)\right],$$

and plugging in equation (A.11) evaluated in $t+1$, one obtains

$$V_{i,t} = E_t\Omega_{it,t+1}\left((R_{k,t+1}-R_t)Q_tS_{iH,t}+(R_{k,t+1}^*-R_t)Q_t^*S_{iF,t}+R_tN_{i,t}\right).$$

Comparing the previous equation to equation (A.4), the guess of the value function, it can be verified that the value function is linear, with

$$\begin{aligned}
\nu_{iH,t} &= E_t\Omega_{it,t+1}(R_{k,t+1} - R_t),\\
\nu_{iF,t} &= E_t\Omega_{it,t+1}(R^*_{k,t+1} - R_t),\\
\eta_{i,t} &= E_t\Omega_{it,t+1}R_t.
\end{aligned}$$

Assuming that in equilibrium all banks are symmetric, subscript i can be dropped, i.e., $\forall i$, $\nu_{iH,t} = \nu_{H,t}$, $\nu_{iF,t} = \nu_{F,t}$, $\eta_{i,t} = \eta_t$ and $\Omega_{it,t+1} = \Omega_{t,t+1}$.

Aggregating over the incentive constraints of the representative banks and taking into account that $\nu_{H,t} = \nu_{F,t}$, one obtains

$$\begin{aligned}
\nu_t B_t + \eta_t N_t &= \lambda_b B_t\\
\Leftrightarrow \frac{B_t}{N_t} &= \frac{\eta_t}{\lambda_b - \nu_t} \equiv \phi_t,
\end{aligned}$$

where ϕ_t, the ratio of intermediated assets to net worth, denotes the time-varying leverage ratio.

A.2 Equilibrium Equations

A.2.1 Original Equilibrium Equations

The following equations constitute the equilibrium equations of the model. Note that only home country equations are shown. Equations (A.12) to (A.16), (A.19) to (A.35) and (A.37) to (A.39) have foreign counterparts while the goods market clearing conditions is associated with an international goods market. Only one aggregate resource constraint is sufficient to determine the equilibrium due to Walras' Law. Hence, there are in total 53 equations in 53 variables, $\beta(C_{A,t})$, $\beta(C^*_{A,t})$, λ_t, λ^*_t, C_t, C^*_t, R_t, R^*_t, L_t, L^*_t, w_t, w^*_t, $\Lambda_{t-1,t}$, $\Lambda^*_{t-1,t}$, $D_{F,t}$, Y_t, Y^*_t, K_t, K^*_t, $R_{k,t}$, $R^*_{k,t}$, Q_t, Q^*_t, I_t, I^*_t, $f(\cdot)$, $f(\cdot)^*$, B_t, B^*_t, ϕ_t, ϕ^*_t, N_t, N^*_t, η_t, η^*_t, ν_t, ν^*_t, $N_{n,t}$, $N^*_{n,t}$, $N_{e,t}$, $N^*_{e,t}$, $\Omega_{t-1,t}$, $\Omega^*_{t-1,t}$, $S_{H,t}$, $S_{F,t}$, $S^*_{H,t}$, $S^*_{F,t}$, A_t, A^*_t, Ψ_t, Ψ^*_t, $\Xi_{N,t}$ and $\Xi^*_{N,t}$. Note that in the representative agent framework, in equilibrium $C_{A,t} = C_t$ and $C^*_{A,t} = C^*_t$.

Households

$$1 = \beta(C_{A,t})E_t\Lambda_{t,t+1}R_t \tag{A.12}$$

$$\Lambda_{t,t+1} = \frac{\lambda_{t+1}}{\lambda_t} \tag{A.13}$$

$$\lambda_t = C_t^{-1} \tag{A.14}$$

$$\beta(C_{A,t}) = \omega_c(1 + C_{A,t})^{-\eta_c} \tag{A.15}$$

$$w_t = \chi \frac{L_t^{\phi}}{\lambda_t} \tag{A.16}$$

$$R_t = R_t^*(1-\omega_d)D_{F,t} \tag{A.17}$$

$$\begin{aligned} Y_t + Q_{t-1}^* S_{F,t-1} R_{k,t-1}^* - Q_{t-1} S_{H,t-1}^* R_{k,t-1} + D_{F,t-1} R_{t-1} + 0.5(R_t^* - R_t) D_{F,t} \\ = C_t + [1+f(\cdot)]I_t + Q_t^* S_{F,t} - Q_t S_{H,t}^* + D_{F,t} \end{aligned} \tag{A.18}$$

Banks

$$B_t = \phi_t N_t \tag{A.19}$$

$$\phi_t = \frac{\eta_t}{\lambda_b - \nu_t} \tag{A.20}$$

$$B_t = Q_t S_{H,t} + Q_t^* S_{F,t} \tag{A.21}$$

$$N_{e,t} = \theta_b \left[\left((R_{k,t} - R_{t-1}) - \frac{Q_{t-1}^* S_{F,t-1}}{B_{t-1}} (R_{k,t} - R_{k,t}^*) \right) \phi_{t-1} + R_{t-1} \right] N_{t-1}, \tag{A.22}$$

$$N_{n,t} = \omega_b (Q_{t-1} S_{H,t-1} + Q_{t-1}^* S_{F,t-1}) \tag{A.23}$$

$$N_t = N_{n,t} + N_{e,t}\, \Xi_{N,t} \tag{A.24}$$

$$\nu_{H,t} = E_t \Omega_{t,t+1} (R_{k,t+1} - R_t) \tag{A.25}$$

$$\eta_t = E_t \Omega_{t,t+1} R_t \tag{A.26}$$

$$E_t \Omega_{t,t+1} R_{k,t+1} = E_t \Omega_{t,t+1} R_{k,t+1}^* \tag{A.27}$$

$$\Omega_{t,t+1} = \beta(C_{A,t}) \Lambda_{t,t+1} \left[(1-\theta_b) + \theta_b \left(\eta_{t+1} + \nu_{t+1} \phi_{t+1} \right) \right] \tag{A.28}$$

Final Goods Firms

$$Y_t = A_t (\Psi_t K_{t-1})^{\alpha} L_t^{1-\alpha} \tag{A.29}$$

$$K_t = I_t + (1-\delta)\Psi_t K_{t-1}, \tag{A.30}$$

$$R_{k,t+1} = \frac{\alpha \frac{Y_{t+1}}{K_t} + (1-\delta)\Psi_{t+1} Q_{t+1}}{Q_t} \tag{A.31}$$

$$w_t = (1-\alpha) \frac{Y_t}{L_t} \tag{A.32}$$

Capital Goods Producers

$$f(\cdot) = \frac{\eta_I}{2} \left(\frac{I_t}{\delta K_{t-1}} - 1 \right)^2 \frac{\delta K_{t-1}}{I_t} \tag{A.33}$$

$$Q_t = 1 + \eta_I \left(\frac{I_t}{\delta K_{t-1}} - 1 \right) \tag{A.34}$$

Market Clearing Conditions

$$Q_t K_t = Q_t(S_{H,t} + S^*_{H,t}) \tag{A.35}$$

$$Y_t + Y^*_t = C_t + C^*_t + [1 + f(\cdot)]I_t + [1 + f^*(\cdot)]I^*_t \tag{A.36}$$

Exogenous Processes

$$\ln \Psi_t = \rho_\Psi \ln \Psi_{t-1} + \epsilon^\Psi_t \tag{A.37}$$

$$\ln A_t = \rho_A \ln A_{t-1} + \epsilon^A_t \tag{A.38}$$

$$\ln \Xi_{N,t} = \rho_N \ln \Xi_{N,t-1} + \epsilon^N_t \tag{A.39}$$

A.2.2 Modified Equilibrium Equations

To solve the model with the method proposed by Devereux and Sutherland (2007; 2008; 2011a), it needs to be rewritten such that portfolio holdings always appear in a product with future excess returns. More specifically, to be able to solve for foreign capital shares directly, the equations are rewritten in a way that $\frac{Q^*_t S_{F,t}}{B_t}$ and $\frac{Q_t S^*_{H,t}}{B^*_t}$ always appear in a product with future excess returns. Then, I replace $\frac{Q^*_{t-1} S_{F,t-1}}{B_{t-1}}(R_{k,t} - R^*_{k,t})$ and $\frac{Q_{t-1} S^*_{H,t-1}}{B^*_{t-1}}(R_{k,t} - R^*_{k,t})$ by $\gamma\xi_t$ (this procedure is described in section 4.4). The resulting set of equilibrium equations contains three equations less: The home and foreign capital market clearing conditions, (A.35) and (A.35*), are replaced by one international capital market clearing condition (equation (A.61)). Equation (A.21) and its foreign counterpart are dropped. Only one portfolio choice equation (equation (A.27)) is needed to solve for the equilibrium, hence, the foreign counterpart (equation (A.27*)) is dropped. An equation defining ξ_t as pure white noise is added. Variables $S_{H,t}$, $S_{F,t}$, $S^*_{H,t}$ and $S^*_{F,t}$ are no longer part of the equilibrium.

Households

$$1 = \beta(C_{A,t}) E_t \Lambda_{t,t+1} R_t \tag{A.40}$$

$$\Lambda_{t,t+1} = \frac{\lambda_{t+1}}{\lambda_t} \tag{A.41}$$

$$\lambda_t = C_t^{-1} \tag{A.42}$$

$$\beta(C_{A,t}) = \omega_c(1 + C_{A,t})^{-\eta_c} \tag{A.43}$$

$$w_t = \chi \frac{L^\phi_t}{\lambda_t} \tag{A.44}$$

$$R_t = R^*_t(1 - \omega_d) D_{F,t} \tag{A.45}$$

$$\frac{Y_t - R_{k,t}Q_{t-1}K_{t-1} + R_{k,t}\phi_{t-1}N_{t-1} + D_{F,t-1}R_{t-1} + 0.5(R_t^* - R_t)D_{F,t}}{B_{t-1}} - \gamma\xi_t$$
$$= \frac{C_t + [1+f(\cdot)]I_t + \phi_t N_t - Q_t K_t + D_{F,t}}{B_{t-1}} \tag{A.46}$$

Final Goods Firms

$$Y_t = A_t(\Psi_t K_{t-1})^{\alpha} L_t^{1-\alpha} \tag{A.47}$$

$$K_t = I_t + (1-\delta)\Psi_t K_{t-1}, \tag{A.48}$$

$$R_{k,t+1} = \frac{\alpha\frac{Y_{t+1}}{K_t} + (1-\delta)\Psi_{t+1}Q_{t+1}}{Q_t} \tag{A.49}$$

$$w_t = (1-\alpha)\frac{Y_t}{L_t} \tag{A.50}$$

Capital Goods Firms

$$f(\cdot) = \frac{\eta_I}{2}\left(\frac{I_t}{\delta K_{t-1}} - 1\right)^2 \frac{\delta K_{t-1}}{I_t} \tag{A.51}$$

$$Q_t = 1 + \eta_I\left(\frac{I_t}{\delta K_{t-1}} - 1\right)$$

Banks

$$B_t = \phi_t N_t \tag{A.52}$$

$$\phi_t = \frac{\eta_t}{\lambda_b - \nu_t} \tag{A.53}$$

$$N_{e,t} = \theta_b\left[\left((R_{k,t} - R_{t-1}) - \gamma\xi_t\right)\phi_{t-1} + R_{t-1}\right]N_{t-1} \tag{A.54}$$

$$N_{n,t} = \omega_b B_{t-1} \tag{A.55}$$

$$N_t = N_{n,t} + N_{e,t}\,\Xi_{N,t} \tag{A.56}$$

$$\nu_{H,t} = E_t\Omega_{t,t+1}(R_{k,t+1} - R_t) \tag{A.57}$$

$$\eta_t = E_t\Omega_{t,t+1}R_t \tag{A.58}$$

$$E_t\Omega_{t,t+1}R_{k,t+1} = E_t\Omega_{t,t+1}R_{k,t+1}^* \tag{A.59}$$

$$\Omega_{t,t+1} = \beta(C_{A,t})\Lambda_{t,t+1}\left[(1-\theta_b) + \theta_b\left(\eta_{t+1} + \nu_{t+1}\phi_{t+1}\right)\right] \tag{A.60}$$

Market Clearing Conditions

$$Q_t K_t + Q_t^* K_t^* = Q_t B_t + Q_t^* B_t^* \tag{A.61}$$

$$Y_t + Y_t^* = C_t + C_t^* + [1+f(\cdot)]I_t + [1+f^*(\cdot)]I_t^* \tag{A.62}$$

Exogenous Processes

$$\ln \Psi_t = \rho_\Psi \ln \Psi_{t-1} + \epsilon_t^\Psi \tag{A.63}$$

$$\ln A_t = \rho_A \ln A_{t-1} + \epsilon_t^A \tag{A.64}$$

$$\ln \Xi_{N,t} = \rho_N \ln \Xi_{N,t-1} + \epsilon_t^N \tag{A.65}$$

$$\xi_t = \epsilon_t^\xi \tag{A.66}$$

A.3 Further Impulse Responses

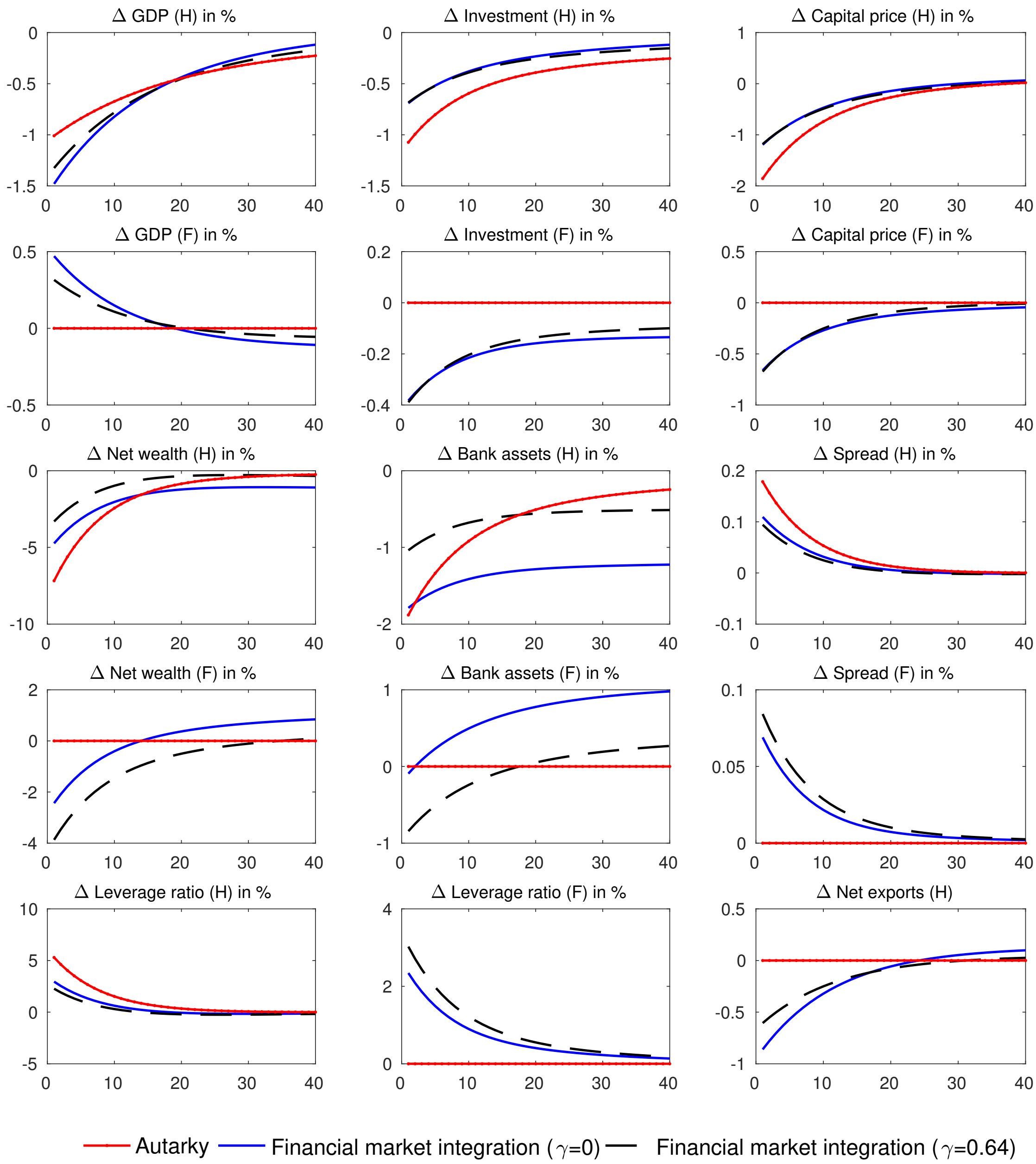

Figure A.1: *Impulse Responses to an Adverse 1% Home Technology Shock*

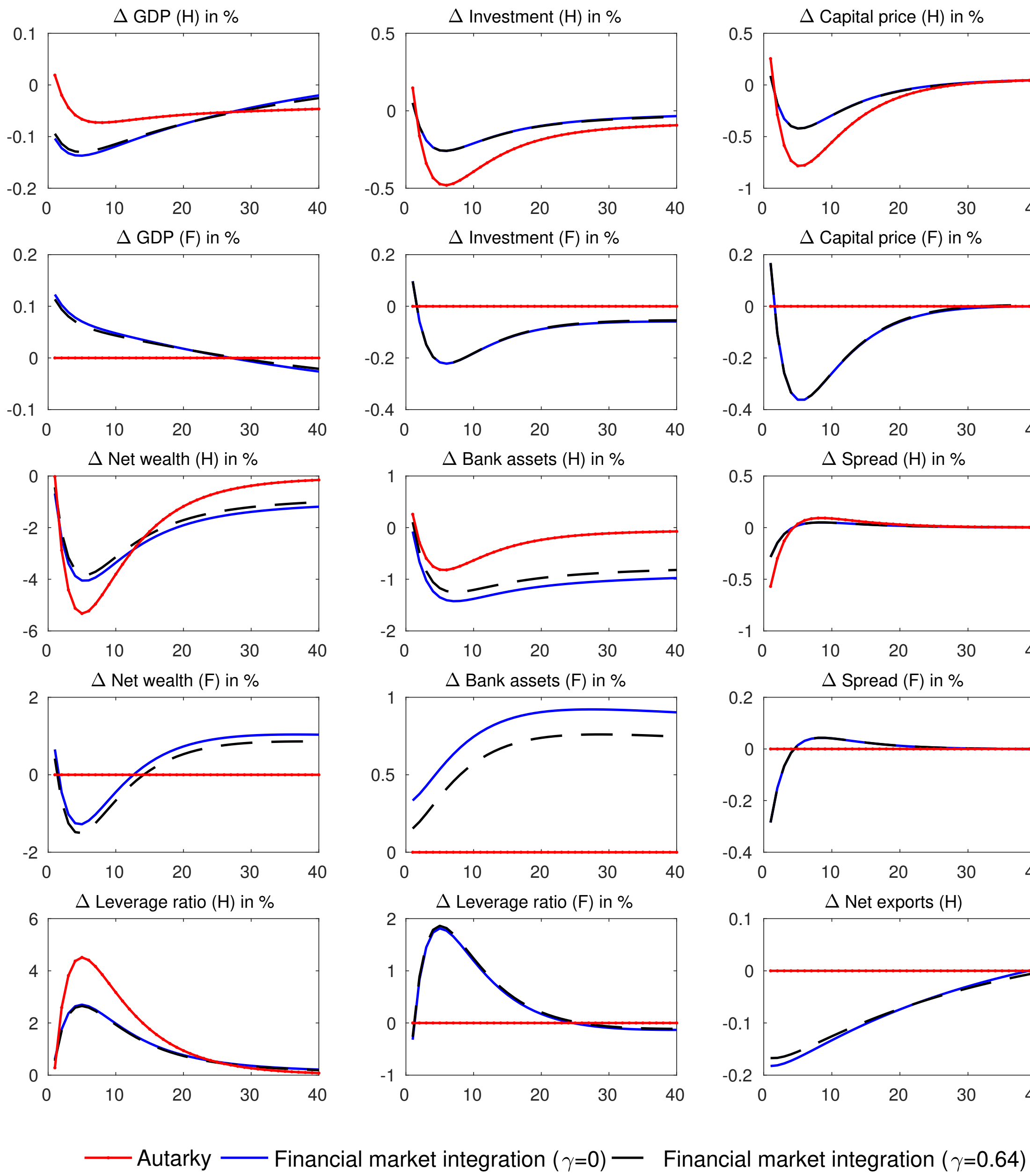

Figure A.2: *Impulse Responses to an Adverse 1% Home Net Wealth Shock*

A.4 Robustness Analyses

A.4.1 Higher Bond Market Integration

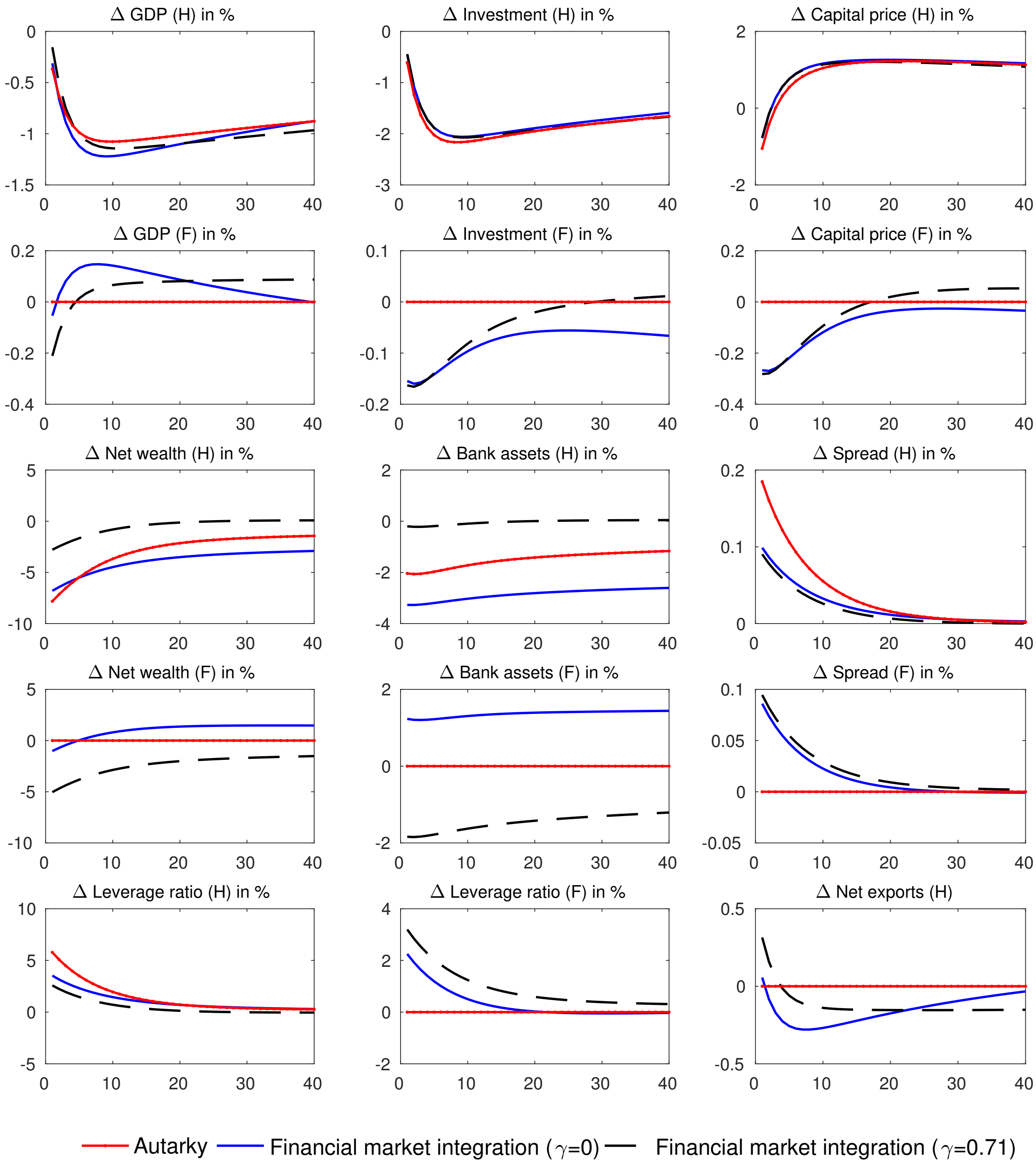

Figure A.3: *Impulse Responses to an Adverse 1% Home Capital Quality Shock with Higher Bond Market Integration* ($\omega_d = 0.001$)

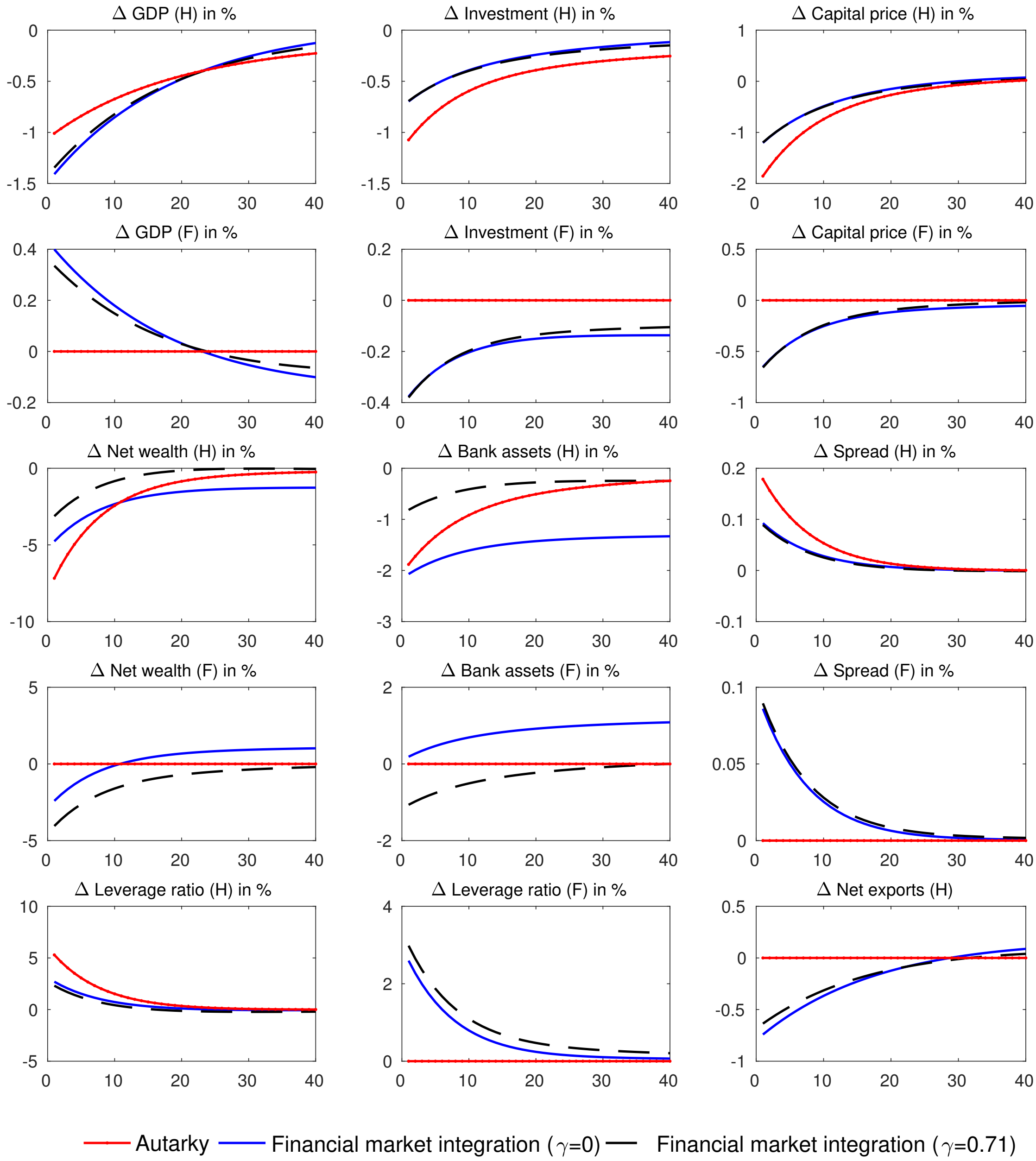

Figure A.4: *Impulse Responses to an Adverse 1% Home Technology Shock with Higher Bond Market Integration* ($\omega_d = 0.001$)

A.4.2 Two-Good Model with Sticky Prices

The following impulse responses result from a two-country model with trade in imperfectly substitutable home and foreign final goods and nominal rigidities. The household sector is modeled exactly as in the original model, except for the fact that households now consume a basket consisting of home and foreign goods. There is no home bias in consumption. As in chapter 3, the elasticity of substitution between home and foreign goods, denoted by ι, is set to four. However, as the trade elasticity seems to matter greatly for the transmission of technology shocks, I also provide the impulse responses to a home technology shock under the assumption of a lower trade elasticity of $\iota = 1.5$ (see figure A.8). Furthermore, it is assumed that final goods prices are sticky. Imperfect price adjustment is modeled as proposed by Calvo (1983). As in chapter 3, the probability of keeping prices fixed, denoted by θ, is set to 0.779 and the elasticity of substitution between varieties, ϵ, is set to 4.167. Banks and capital goods producing firms are modeled exactly as in the original model. Final goods are now produced in a two-stage production process, however, the production function remains unchanged. It should be noted that financial market autarky (red lines) no longer implies full autarky, as two goods are traded.

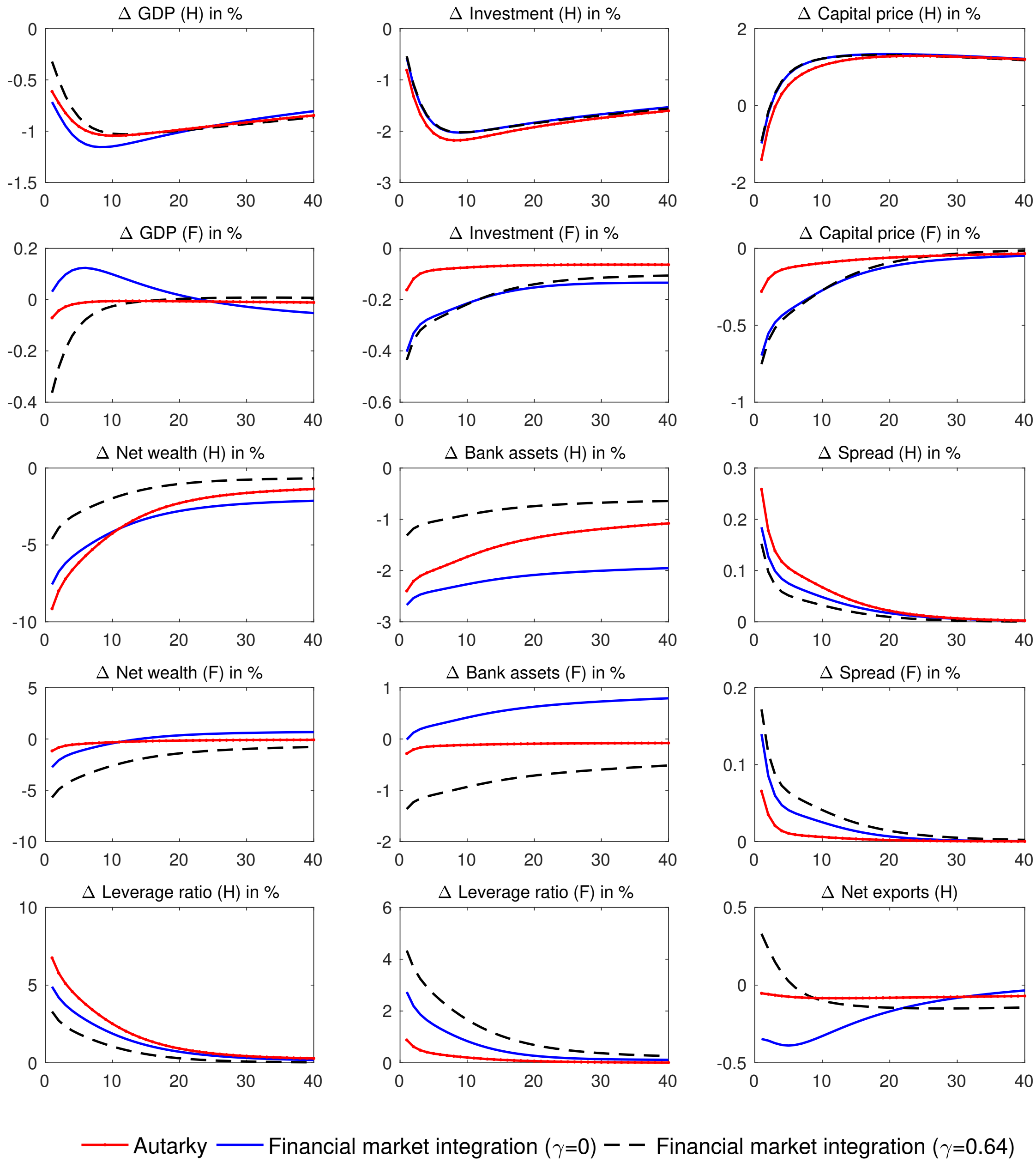

Figure A.5: *Impulse Responses to an Adverse 1% Home Capital Quality Shock in a Two-Good Model with Sticky Prices* ($\iota = 4$)

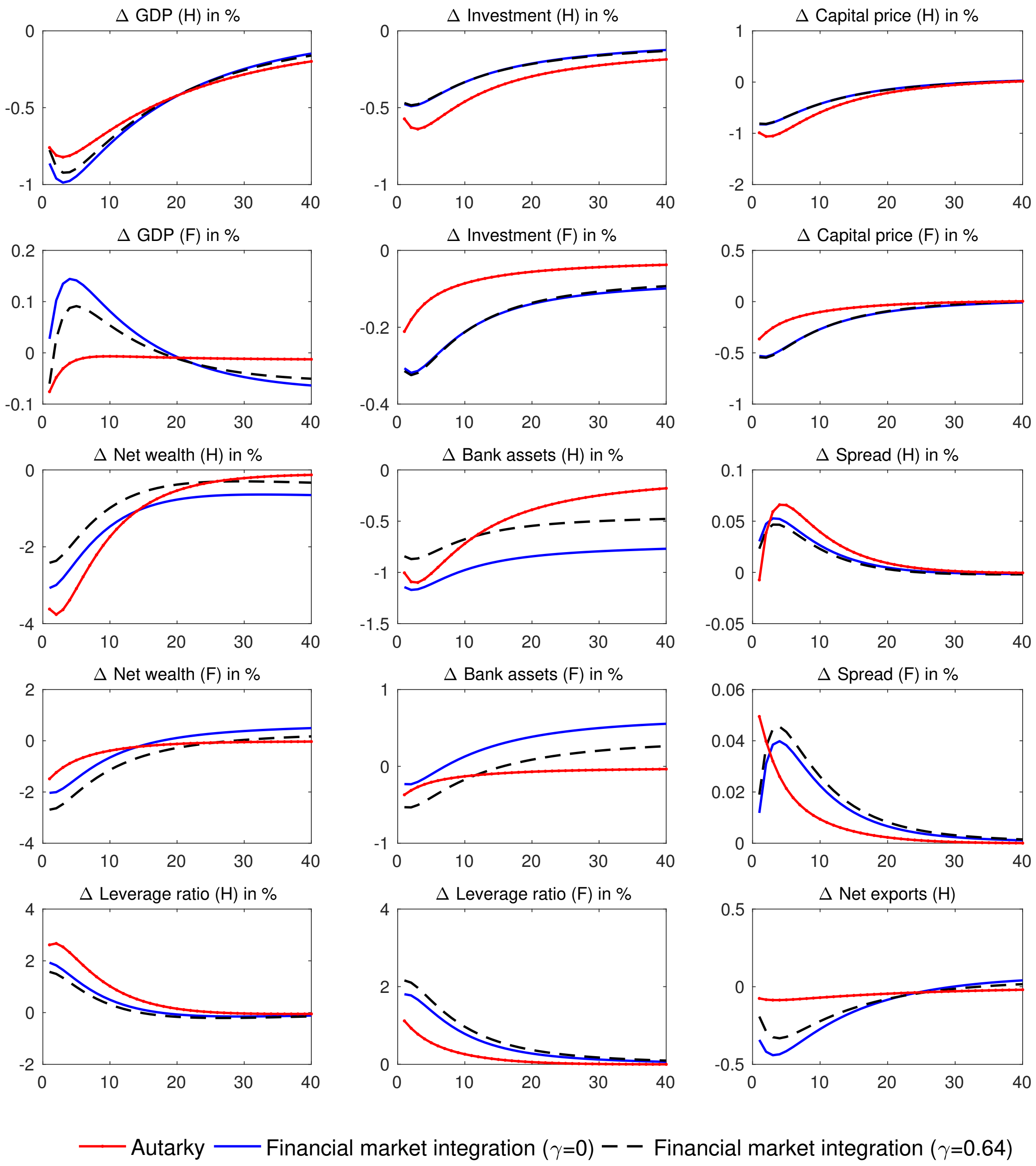

Figure A.6: *Impulse Responses to an Adverse 1% Home Technology Shock in a Two-Good Model with Sticky Prices* ($\iota = 4$)

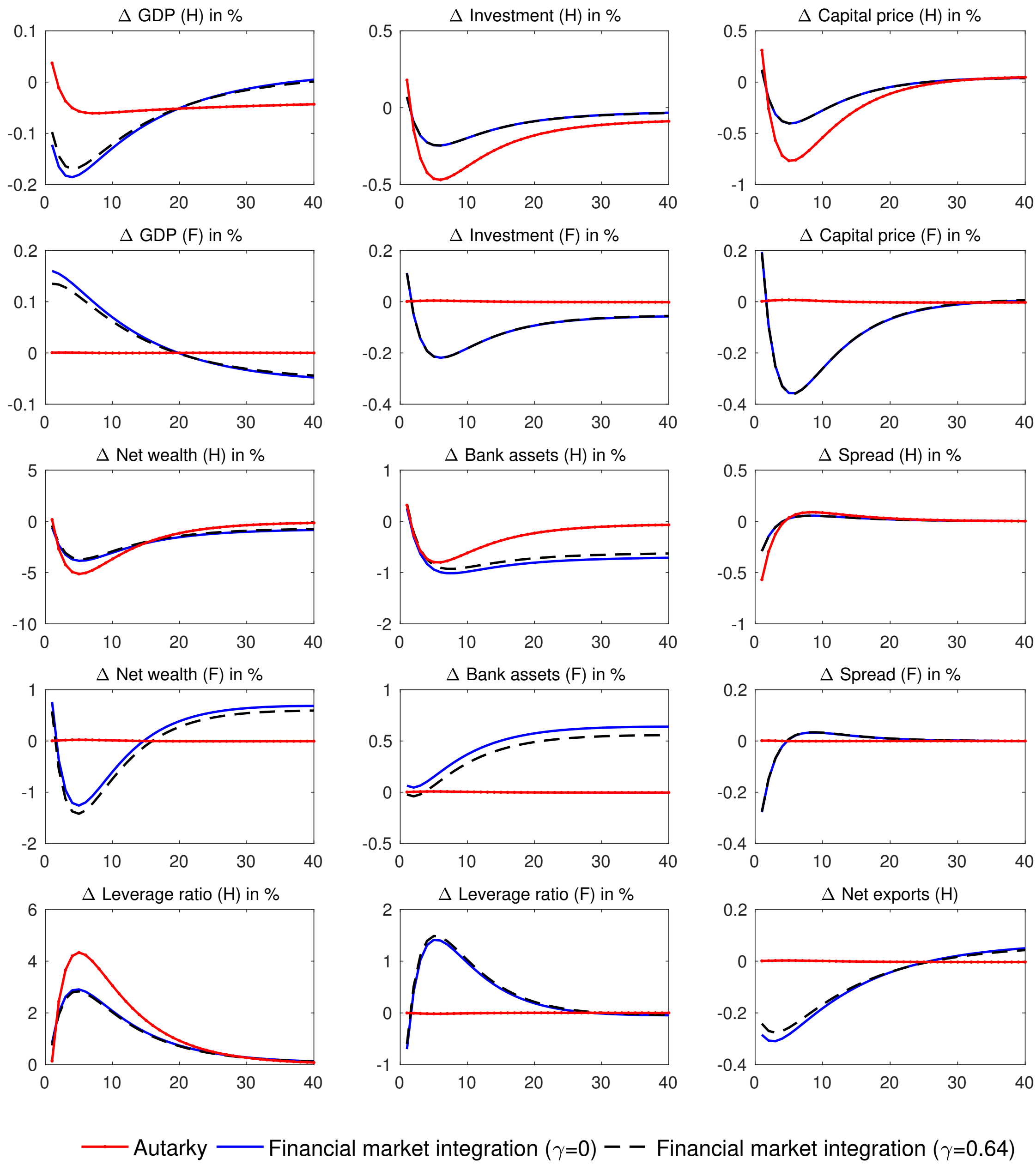

Figure A.7: *Impulse Responses to an Adverse 1% Home Net Wealth Shock Shock in a Two-Good Model with Sticky Prices* ($\iota = 4$)

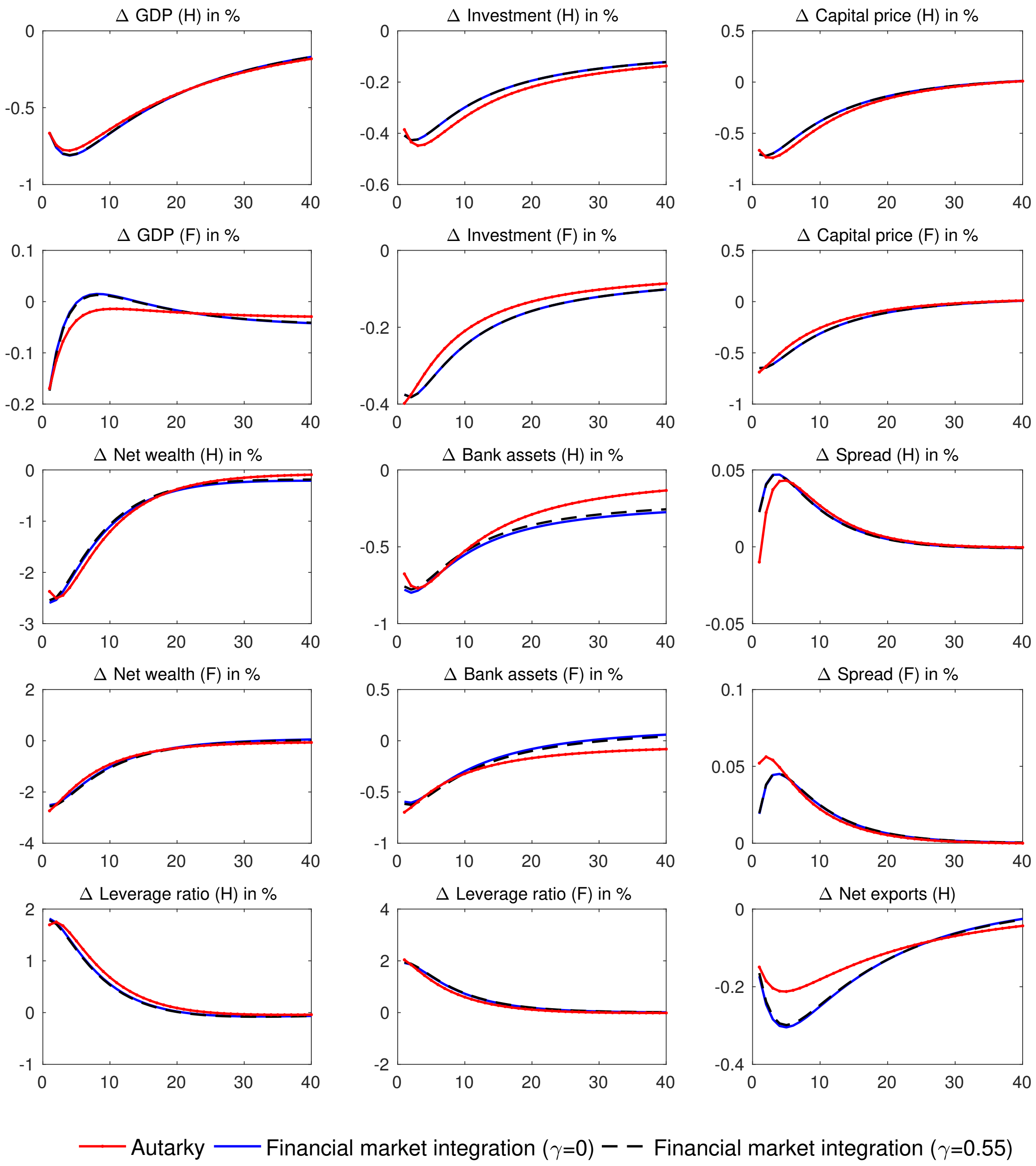

Figure A.8: *Impulse Responses to an Adverse 1% Home Technology Shock in a Two-Good Model with Sticky Prices and a Lower Trade Elasticity* ($\iota = 1.5$)

Appendix B

Appendix to Chapter 3

B.1 CES Portfolio Choice

The asset portfolio of bank i, $B_{i,t}$, consists of home as well as foreign assets which are combined according to the following CES aggregator

$$B_{i,t} = \left(\mu_b^{\frac{1}{\iota_b}} \left(Q_t S_{iH,t}\right)^{\frac{\iota_b - 1}{\iota_b}} + (1 - \mu_b)^{\frac{1}{\iota_b}} \left(Q_t^* S_{iF,t}\right)^{\frac{\iota_b - 1}{\iota_b}} \right)^{\frac{\iota_b}{\iota_b - 1}}. \tag{B.1}$$

The corresponding price index, which specifies the average expected return on the asset portfolio, R_t^A, in terms of the expected returns of the home and foreign assets, $R_{k,t}$ and $R_{k,t}^*$, is given by

$$\frac{1}{R_t^A} = \left(\mu_b \left(\frac{1}{R_{k,t}} \right)^{1-\iota_b} + (1 - \mu_b) \left(\frac{1}{R_{k,t}^*} \right)^{1-\iota_b} \right)^{\frac{\iota_b}{\iota_b - 1}}. \tag{B.2}$$

The optimal home and foreign asset purchases can be obtained by finding the minimum of the following equation

$$\begin{aligned} \frac{1}{R_{t+1}^A} B_{i,t} &= E_t \left\{ R_{k,t+1} Q_t S_{iH,t} + R_{k,t+1}^* Q_t^* S_{iF,t} \right\} \\ \Leftrightarrow B_{i,t} &= E_t \left\{ \frac{R_{t+1}^A}{R_{k,t+1}} Q_t S_{iH,t} + \frac{R_{t+1}^A}{R_{k,t+1}^*} Q_t^* S_{iF,t} \right\}, \end{aligned} \tag{B.3}$$

subject to equation (B.1). Expressions $\frac{R_{t+1}^A}{R_{k,t+1}}$ and $\frac{R_{t+1}^A}{R_{k,t+1}^*}$ can be interpreted as relative expected asset prices. Equation (B.3) can be interpreted as expectation-adjusted portfolio expenditures. Minimizing expectation-adjusted portfolio expenditures is essentially the same as maximizing expected portfolio returns. Solutions to the optimization problem are given by the following asset demand equations

$$Q_t S_{iH,t} = \mu_b E_t \left(\frac{R_{k,t+1}}{R^A_{t+1}}\right)^{\iota_b} B_{i,t}, \tag{B.4}$$

$$Q^*_t S_{iF,t} = (1-\mu_b) E_t \left(\frac{R^*_{k,t+1}}{R^A_{t+1}}\right)^{\iota_b} B_{i,t}. \tag{B.5}$$

B.2 Equilibrium Equations

B.2.1 Equilibrium Equations without Central Bank Credit Policy

The following equations constitute the equilibrium equations of the model. Note that only home country equations are shown. Equations (B.12), (B.13), (B.17),(B.20), (B.21) and (B.45) do not have foreign counterparts. Hence, there are in total 84 equations in 84 variables, $\beta(C_{A,t})$, $\beta(C^*_{A,t})$, λ_t, λ^*_t, C_t, C^*_t, R_t, R^*_t, L_t, L^*_t, w_t, w^*_t, $\Lambda_{t-1,t}$, $\Lambda^*_{t-1,t}$, $D_{F,t}$, Y_t, Y^*_t, K_t, K^*_t, $R_{k,t}$, $R^*_{k,t}$, Q_t, Q^*_t, I_t, I^*_t, $f(\cdot)$, $f(\cdot)^*$, B_t, B^*_t, ϕ_t, ϕ^*_t, N_t, N^*_t, η_t, η^*_t, ν_t, ν^*_t, $N_{n,t}$, $N^*_{n,t}$, $N_{e,t}$, $N^*_{e,t}$, $\Omega_{t-1,t}$, $\Omega^*_{t-1,t}$, $S_{H,t}$, $S_{F,t}$, $S^*_{H,t}$, $S^*_{F,t}$, R^A_t, R^{*A}_t, i_t, i^*_t, i^{CB}_t, π^{int}_t, $I_{n,t}$, $I^*_{n,t}$, $C_{H,t}$, $C_{F,t}$, $C^*_{H,t}$, $C^*_{F,t}$, $p_{H,t}$, $p_{F,t}$, Π_t, $\Pi_{H,t}$, $\Pi_{F,t}$, $\tilde{\Pi}_{H,t}$, $\tilde{\Pi}_{F,t}$, $Y_{m,t}$, $Y^*_{m,t}$, $P_{m,t}$, $P^*_{m,t}$, U_t, U^*_t, $\delta(U_t)$, $\delta(U^*_t)$, $\Delta_{p,t}$, $\Delta^*_{p,t}$, X_t X^*_t, A_t, A^*_t, Ψ_t, Ψ^*_t, $\Xi_{N,t}$ and $\Xi^*_{N,t}$. Note that $p_{H,t} \equiv \frac{P_{H,t}}{P_t} = \frac{P^*_{H,t}}{P^*_t}$, $p_{F,t} \equiv \frac{P_{F,t}}{P_t} = \frac{P^*_{F,t}}{P^*_t}$, $\tilde{\Pi}_{H,t} \equiv \frac{\tilde{P}_{H,t}}{P_{H,t-1}}$ and Π_t is union-wide consumer price inflation.

Households

$$\beta(C_{A,t}) = \omega_c(1+C_{A,t})^{-\eta_c} \tag{B.6}$$

$$\lambda_t = (C_t - hC_{t-1})^{-1} - \beta(C_{A,t})h(E_tC_{t+1} - hC_t)^{-1} \tag{B.7}$$

$$1 = \beta(C_{A,t})E_t\Lambda_{t,t+1}R_t \tag{B.8}$$

$$i_t = i^{CB}_t(1-\omega_d D_{F,t}) \tag{B.9}$$

$$w_t = \chi\frac{L^\phi_t}{\lambda_t} \tag{B.10}$$

$$\Lambda_{t,t+1} = \frac{\lambda_{t+1}}{\lambda_t} \tag{B.11}$$

$$\begin{aligned} p_{H,t}Y_t + Q^*_{t-1}S_{F,t-1}R^*_{k,t} - Q_{t-1}S^*_{H,t-1}R_{k,t} + D_{F,t-1}\frac{i_{t-1}}{\Pi_t} + \Upsilon^{\mathrm{IFI}}_t \\ = C_t + D_{F,t} + \left[I_t + f\left(\frac{I_{n,t}+I}{I_{n,t-1}+I}\right)(I_{n,t}+I)\right] \\ +Q^*_tS_{F,t} - Q_tS^*_{H,t} + 0.5(\Gamma_{m,t}+\Gamma_{f,t}) \end{aligned} \tag{B.12}$$

$$\Upsilon_t^{\mathrm{IFI}} = -\left(\frac{1}{\Phi(-D_{F,t})} - 1\right)\frac{D_{F,t}}{i_t^{CB}} \tag{B.13}$$

$$C_{H,t} = 0.5 p_{H,t}^{-\epsilon} C_t \tag{B.14}$$

$$C_{F,t} = 0.5 p_{F,t}^{-\epsilon} C_t \tag{B.15}$$

$$1 = \left(0.5 p_{H,t}^{1-\iota} + 0.5 p_{F,t}^{1-\iota}\right)^{\frac{1}{1-\iota}} \tag{B.16}$$

$$\Pi_t = \Pi_{H,t}\frac{p_{H,t-1}}{p_{H,t}} \tag{B.17}$$

Banks

$$\frac{1}{R_t^A} = \left(\mu_b\left(\frac{1}{R_{k,t}}\right)^{1-\iota_b} + (1-\mu_b)\left(\frac{1}{R_{k,t}^*}\right)^{1-\iota_b}\right)^{\frac{\iota_b}{\iota_b-1}} \tag{B.18}$$

$$B_t = \left(\mu_b^{\frac{1}{\iota_b}}(Q_t S_{H,t})^{\frac{\iota_b-1}{\iota_b}} + (1-\mu_b)^{\frac{1}{\iota_b}}(Q_t^* S_{F,t})^{\frac{\iota_b-1}{\iota_b}}\right)^{\frac{\iota_b}{\iota_b-1}} \tag{B.19}$$

$$Q_t S_{H,t} = \mu_b E_t\left(\frac{R_{k,t+1}}{R_{t+1}^A}\right)^{\iota_b} B_t \tag{B.20}$$

$$Q_t^* S_{F,t} = (1-\mu_b) E_t\left(\frac{R_{k,t+1}^*}{R_{t+1}^A}\right)^{\iota_b} B_t \tag{B.21}$$

$$\nu_t = E_t\Omega_{t,t+1}(R_{t+1}^A - R_t) \tag{B.22}$$

$$\eta_t = E_t\Omega_{t,t+1}R_t \tag{B.23}$$

$$B_t = \phi_t N_t \tag{B.24}$$

$$\phi_t = \frac{\eta_t}{\lambda_b - \nu_t} \tag{B.25}$$

$$N_t = N_{n,t} + N_{e,t}\Xi_{N,t} \tag{B.26}$$

$$N_{e,t} = \theta_b\left[(R_t^A - R_{t-1})\phi_{t-1} + R_{t-1}\right]N_{t-1} \tag{B.27}$$

$$N_{n,t} = \omega_b B_{t-1} \tag{B.28}$$

$$\Omega_{t,t+1} = \beta(C_{A,t})\Lambda_{t,t+1}\left[(1-\theta_b) + \theta_b\left(\eta_{t+1} + \nu_{t+1}\phi_{t+1}\right)\right] \tag{B.29}$$

Intermediate Goods Firms

$$Y_{m,t} = A_t(U_t\Psi_t K_{t-1})^{\alpha} L_t^{1-\alpha} \tag{B.30}$$

$$K_t = I_t + (1-\delta(U_t))\Psi_t K_{t-1} \tag{B.31}$$

$$w_t = (1-\alpha)\frac{P_{m,t}Y_{m,t}}{L_t} \tag{B.32}$$

$$\delta'(U_t)\Psi_t K_{t-1} = P_{m,t}\alpha\frac{Y_{m,t}}{U_t} \tag{B.33}$$

$$R_{k,t+1} = \frac{\alpha\frac{P_{m,t+1}Y_{m,t+1}}{K_t} + (Q_{t+1} - \delta(U_{t+1}))\Psi_{t+1}}{Q_t} \tag{B.34}$$

$$\delta(U_t) = \delta_u + \frac{b}{1+\zeta}U_t^{1+\zeta} \tag{B.35}$$

Capital Goods Firms

$$f\left(\frac{I_{n,t}+I}{I_{n,t-1}+I}\right) = \frac{\eta_I}{2}\left(\frac{I_{n,t}+I}{I_{n,t-1}+I} - 1\right)^2 \tag{B.36}$$

$$I_{n,t} = I_t - \delta(U_t)\Psi_t K_{t-1} \tag{B.37}$$

$$Q_t = 1 - f(\cdot) + \frac{I_{n,t}+I}{I_{n,t-1}+I}f'(\cdot) - E_t\beta(C_{A,t})\Lambda_{t,t+1}\left(\frac{I_{n,t+1}+I}{I_{n,t}+I}\right)^2 f'(\cdot) \tag{B.38}$$

Final Goods Firms

$$X_t = \frac{p_{H,t}}{P_{m,t}} \tag{B.39}$$

$$\tilde{\Pi}_{H,t} = \frac{\epsilon}{\epsilon-1}\frac{E_t\sum_{k=0}^{\infty}\theta^k\Theta_k\lambda_{t+k}\Pi_{H,t,t+k}^{\epsilon}\Pi_{H,t-1,t+k-1}^{-\epsilon\theta_\pi}Y_{t+k}P_{m,t+k}}{E_t\sum_{k=0}^{\infty}\theta^k\Theta_k\lambda_{t+k}\Pi_{H,t,t+k}^{\epsilon-1}\Pi_{H,t-1,t+k-1}^{(1-\epsilon)\theta_\pi}Y_{t+k}p_{H,t+k}}\Pi_{H,t} \tag{B.40}$$

$$Y_{m,t} = Y_t\Delta_{p,t} \tag{B.41}$$

$$\Delta_{p,t} = \theta\Delta_{p,t-1}\Pi_{H,t}^{\epsilon}\Pi_{H,t-1}^{-\epsilon\theta_\pi} + (1-\theta)\left(\frac{1-\theta\Pi_{H,t}^{\epsilon-1}\Pi_{H,t-1}^{\theta_\pi(1-\epsilon)}}{1-\theta}\right)^{\frac{\epsilon}{\epsilon-1}} \tag{B.42}$$

$$\Pi_{H,t} = \left(\theta\Pi_{H,t-1}^{\theta_\pi(1-\epsilon)} + (1-\theta)\tilde{\Pi}_{H,t}^{1-\epsilon}\right)^{\frac{1}{1-\epsilon}} \tag{B.43}$$

Central Bank

$$i_t = R_t E_t \Pi_{t+1} \tag{B.44}$$

$$i_t^{CB} = \left(\beta\Pi_t^{\gamma_\pi}X_t^{-0.5\gamma_y}X_t^{*-0.5\gamma_y}\right)^{1-\rho_i}\left(i_{t-1}^{CB}\right)^{\rho_i}\varepsilon_{M,t} \tag{B.45}$$

Market Clearing

$$Q_t K_t = Q_t(S_{H,t} + S^*_{H,t}) \tag{B.46}$$

$$Y_t = C_{H,t} + C^*_{H,t} + p^{-1}_{H,t}[I_t + f\left(\frac{I_{n,t}+I}{I_{n,t-1}+I}\right)(I_{n,t}+I)] \tag{B.47}$$

Exogenous Processes

$$\Psi_t = (1-\rho_\Psi) + \rho_\Psi \Psi_{t-1} + \epsilon^\Psi_t \tag{B.48}$$

$$A_t = (1-\rho_A) + \rho_A A_{t-1} + \epsilon^A_t \tag{B.49}$$

$$\Xi_{N,t} = (1-\rho_N) + \rho_N \Xi_{N,t-1} + \epsilon^N_t \tag{B.50}$$

B.2.2 Additional Equilibrium Equations with Central Bank Credit Policy

Liquidity Facilities

In the model with liquidity facilities, there are nine additional variables, M_t, M^*_t, $R_{m,t}$, $R^*_{m,t}$, $\eta_{m,t}$, $\eta^*_{m,t}$, $\Gamma_{m,t}$, $\Phi_{m,t}$ and $\Phi^*_{m,t}$ (if it is assumed that the central bank follows a union-wide rule, there is only one union-wide $\Phi_{m,t}$, hence, only eight additional variables). Correspondingly, nine (or eight, in the case of a union-wide rule) equations are added to the system of equations which was laid out in subsection B.2.1 (only home country equations will be displayed). Equation (B.55) does not have a foreign counterpart, as intervention costs accrue to the union-wide central bank.

$$\eta_{m,t} = E_t\Omega_{t,t+1}(R_{m,t} - R_t). \tag{B.51}$$

$$\eta_{m,t} = \lambda_m \nu_t, \tag{B.52}$$

$$M_t = \Phi_{m,t} B_t. \tag{B.53}$$

$$\text{Policy rule for } \Phi_{m,t} \tag{B.54}$$

$$\Gamma_{m,t} = \tau_1(M_t + M^*_t) + \tau_2(M^2_t + M^{*2}_t) \tag{B.55}$$

Equations (B.24) and (B.27) are replaced.

$$B_t = \phi_t N_t + \lambda_m M_t \tag{B.24'}$$

$$N_{e,t} = \theta_b \left[(R_t^A - R_{t-1}) \frac{\phi_{t-1}}{1 - \lambda_m \Phi_{m,t-1}} - (R_{t-1}^m - R_{t-1}) \frac{\phi_{t-1}\Phi_{m,t-1}}{1 - \lambda_m \Phi_{m,t-1}} + R_{t-1} \right] N_{t-1} \tag{B.27'}$$

Corporate Sector Credit Policy

In the model with corporate sector credit policy, there are five additional variables, F_t, F_t^*, $\Gamma_{f,t}$, $\Phi_{f,t}$ and $\Phi_{f,t}^*$ (if it is assumed that the central bank follows a union-wide rule, there is only one union-wide $\Phi_{f,t}$, hence, only four additional variables). Correspondingly, five (or four, in the case of a union-wide rule) equations are added to the system of equations which was laid out in subsection B.2.1 (only home country equations will be displayed). Equation (B.58) does not have a foreign counterpart, as intervention costs accrue to the union-wide central bank. Equation (B.46) needs to be replaced.

$$F_t = \Phi_{f,t} Q_t K_t \tag{B.56}$$

$$\text{Policy rule for } \Phi_{f,t} \tag{B.57}$$

$$\Gamma_{f,t} = \tau_1 (F_t + F_t^*) + \tau_2 (F_t^2 + F_t^{*2}) \tag{B.58}$$

$$(1 - \Phi_{f,t}) Q_t K_t = Q_t (S_{h,t} + S_{h,t}^*) \tag{B.46'}$$

Furthermore, in the case of any central bank credit policy, variables T_t and T_t^* and the following equation and its foreign counterpart are added to the system of equilibrium equations.

$$0.5(\Gamma_{m,t} + \Gamma_{f,t}) + M_t + F_t = T_t + (R_{m,t-1} - R_{t-1}) M_{t-1} + (R_{k,t} - R_{t-1}) F_{t-1} \tag{B.59}$$

B.3 Further Welfare Tables

	κ_f, κ_m (1)	g (2)	Rel. gain (3)	Risk-sharing (4)	K (5)	N (6)	C (7)	vol(C) (8)	L (9)	vol(L) (10)
No UMP	-	-0.03	-	0.59	5.655	1.424	0.707	0.0382	0.333	0.0207
Rule 1 - Credit Spread Rule										
LF, cou.	0	-0.03	0	0.59	5.655	1.424	0.707	0.0382	0.333	0.0207
LF, un.	0	-0.03	0	0.59	5.655	1.424	0.707	0.0382	0.333	0.0207
CCP, cou.	43	-0.02	0.02	0.59	5.654	1.415	0.707	0.0342	0.333	0.0146
CCP, un.	132	0.03	0.06	0.50	5.656	1.385	0.707	0.0335	0.333	0.0153
Rule 2 - Credit Growth Rule										
LF, cou.	40	0.92	0.95	0.53	5.725	1.379	0.708	0.0334	0.333	0.0304
LF, un.	40	0.67	0.70	0.51	5.701	1.392	0.708	0.0336	0.333	0.0284
CCP, cou.	139	1.50	1.53	0.70	5.770	1.333	0.710	0.0270	0.333	0.0505
CCP, un.	135	1.11	1.14	0.52	5.741	1.354	0.709	0.0294	0.333	0.0473

No UMP: no unconventional monetary policy. LF: liquidity facilities. CCP: corporate credit policy. Cou.: country-specific. Un.: union-wide. κ_f: optimal feedback coefficient for liquidity facilities. κ_m: optimal feedback coefficient for credit policy. g: welfare gains in consumption equivalents in percent of steady-state consumption. Relative gain: difference in g to case without unconventional policy. International risk-sharing is measured as corr(λ_t, λ_t^*). Columns (5)-(7) and (9) display the stochastic steady state of the given variable.

Table B.1: *Optimal Simple Rules in a Symmetric Setup (Only Capital Quality Shocks)*

	κ_f, κ_m (1)	g (2)	Rel. gain (3)	Risk-sharing (4)	K (5)	N (6)	C (7)	vol(C) (8)	L (9)	vol(L) (10)
No UMP	-	-0.16	-	0.41	5.667	1.419	0.707	0.0323	0.333	0.0127
Rule 1 - Credit Spread Rule										
LF, cou.	330	-0.15	0.02	0.39	5.667	1.418	0.707	0.0317	0.333	0.0139
LF, un.	330	-0.15	0.02	0.39	5.667	1.417	0.707	0.0317	0.333	0.0136
CCP, cou.	330	-0.14	0.02	0.40	5.667	1.414	0.707	0.0317	0.333	0.0140
CCP, un.	330	-0.14	0.02	0.39	5.667	1.412	0.707	0.0317	0.333	0.0136
Rule 2 - Credit Growth Rule										
LF, cou.	23	-0.12	0.04	0.39	5.670	1.417	0.707	0.0312	0.333	0.0146
LF, un.	26	-0.12	0.04	0.38	5.669	1.417	0.707	0.0312	0.333	0.0145
CCP, cou.	139	-0.08	0.09	0.42	5.675	1.412	0.707	0.0273	0.333	0.0155
CCP, un.	139	-0.09	0.07	0.33	5.674	1.414	0.707	0.0285	0.333	0.0160

No UMP: no unconventional monetary policy. LF: liquidity facilities. CCP: corporate credit policy. Cou.: country-specific. Un.: union-wide. κ_f: optimal feedback coefficient for liquidity facilities. κ_m: optimal feedback coefficient for credit policy. g: welfare gains in consumption equivalents in percent of steady-state consumption. Relative gain: difference in g to case without unconventional policy. International risk-sharing is measured as corr(λ_t, λ_t^*). Columns (5)-(7) and (9) display the stochastic steady state of the given variable.

Table B.2: *Optimal Simple Rules in a Symmetric Setup (Only Technology Shocks)*

	κ_f, κ_m (1)	g (2)	Rel. gain (3)	Risk-sharing (4)	K (5)	N (6)	C (7)	vol(C) (8)	L (9)	vol(L) (10)
No UMP	-	0.12	-	0.45	5.669	1.409	0.707	0.0076	0.333	0.0133
Rule 1 - Credit Spread Rule										
LF, cou.	13	0.21	0.09	0.38	5.674	1.405	0.708	0.0067	0.333	0.0104
LF, un.	13	0.18	0.07	0.29	5.673	1.406	0.708	0.0069	0.333	0.0113
CCP, cou.	7	0.22	0.10	0.36	5.674	1.405	0.708	0.0068	0.333	0.0103
CCP, un.	7	0.19	0.07	0.29	5.673	1.406	0.708	0.0069	0.333	0.0113
Rule 2 - Credit Growth Rule										
LF, cou.	13	0.16	0.04	0.37	5.671	1.407	0.708	0.0073	0.333	0.0108
LF, un.	13	0.15	0.03	0.36	5.671	1.407	0.708	0.0073	0.333	0.0115
CCP, cou.	10	0.17	0.05	0.33	5.672	1.407	0.708	0.0072	0.333	0.0096
CCP, un.	7	0.15	0.04	0.37	5.671	1.407	0.708	0.0073	0.333	0.0116

No UMP: no unconventional monetary policy. LF: liquidity facilities. CCP: corporate credit policy. Cou.: country-specific. Un.: union-wide. κ_f: optimal feedback coefficient for liquidity facilities. κ_m: optimal feedback coefficient for credit policy. g: welfare gains in consumption equivalents in percent of steady-state consumption. Relative gain: difference in g to case without unconventional policy. International risk-sharing is measured as corr(λ_t, λ_t^*). Columns (5)-(7) and (9) display the stochastic steady state of the given variable.

Table B.3: *Optimal Simple Rules in a Symmetric Setup (Only Net Wealth Shocks)*

	κ_f, κ_m (1)	g (2)	Rel. gain (3)	Risk-sharing (4)	K (5)	N (6)	C (7)	vol(C) (8)	L (9)	vol(L) (10)
No UMP	-	-3.61	-	1.00	5.603	1.518	0.703	0.0334	0.331	0.0754
Rule 1 - Credit Spread Rule										
LF, cou.	92	-3.07	0.55	1.00	5.651	1.495	0.705	0.0237	0.332	0.0393
LF, un.	92	-3.07	0.55	1.00	5.651	1.495	0.705	0.0237	0.332	0.0393
CCP, cou.	284	-2.04	1.57	1.00	5.670	1.160	0.706	0.0163	0.332	0.0267
CCP, un.	284	-2.04	1.57	1.00	5.670	1.160	0.706	0.0163	0.332	0.0267
Rule 2 - Credit Growth Rule										
LF, cou.	89	1.66	5.28	1.00	5.894	1.336	0.712	0.0270	0.333	0.0331
LF, un.	89	1.66	5.28	1.00	5.894	1.336	0.712	0.0270	0.333	0.0331
CCP, cou.	139	2.63	6.24	1.00	5.947	1.290	0.715	0.0231	0.334	0.0204
CCP, un.	139	2.63	6.24	1.00	5.947	1.290	0.715	0.0231	0.334	0.0204

No UMP: no unconventional monetary policy. LF: liquidity facilities. CCP: corporate credit policy. Cou.: country-specific. Un.: union-wide. κ_f: optimal feedback coefficient for liquidity facilities. κ_m: optimal feedback coefficient for credit policy. g: welfare gains in consumption equivalents in percent of steady-state consumption. Relative gain: difference in g to case without unconventional policy. International risk-sharing is measured as corr(λ_t, λ_t^*). Columns (5)-(7) and (9) display the stochastic steady state of the given variable.

Table B.4: *Optimal Simple Rules in a Symmetric Setup (Only Monetary Policy Shocks)*

	κ_f, κ_m (1)	g (2)	Rel. gain (3)	Risk-sharing (4)	K (5)	N (6)	C (7)	vol(C) (8)	L (9)	vol(L) (10)
No UMP	-	-3.92	-	0.61	5.217	1.220	0.687	0.0620	0.328	0.0807
Rule 1 - Credit Spread Rule										
LF, cou.	56	-3.44	0.48	0.58	5.547	1.404	0.701	0.0555	0.331	0.0489
LF, un.	83	-3.34	0.59	0.54	5.599	1.420	0.703	0.0550	0.332	0.0466
CCP, cou.	330	-2.19	1.74	0.56	5.716	1.233	0.707	0.0475	0.333	0.0354
CCP, un.	304	-2.14	1.78	0.50	5.709	1.008	0.706	0.0501	0.333	0.0360
Rule 2 - Credit Growth Rule										
LF, cou.	63	2.63	6.55	0.63	5.878	1.198	0.709	0.0532	0.333	0.0573
LF, un.	69	2.04	5.97	0.56	5.889	1.267	0.710	0.0542	0.333	0.0549
CCP, cou.	139	4.60	8.53	0.64	6.056	1.039	0.715	0.0439	0.335	0.0598
CCP, un.	135	3.55	7.47	0.54	6.025	1.175	0.715	0.0492	0.334	0.0552

No UMP: no unconventional monetary policy. LF: liquidity facilities. CCP: corporate credit policy. Cou.: country-specific. Un.: union-wide. κ_f: optimal feedback coefficient for liquidity facilities. κ_m: optimal feedback coefficient for credit policy. g: welfare gains in consumption equivalents in percent of steady-state consumption. Relative gain: difference in g to case without unconventional policy. International risk-sharing is measured as corr(λ_t, λ_t^*). Columns (5)-(7) and (9) display the stochastic steady state of the given variable.

Table B.5: *Optimal Simple Rules in a Symmetric Setup (Domestic Credit Provision)*

	κ_f, κ_m (1)	g (2)	Rel. gain (3)	Risk-sharing (4)	K (5)	N (6)	C (7)	vol(C) (8)	L (9)	vol(L) (10)
No UMP	-	-3.75	-	0.84	5.601	1.529	0.702	0.0575	0.331	0.0819
Rule 1 - Credit Spread Rule										
LF, cou.	56	-3.31	0.44	0.78	5.646	1.519	0.704	0.0517	0.332	0.0527
LF, un.	73	-3.23	0.52	0.82	5.642	1.516	0.704	0.0504	0.332	0.0496
CCP, cou.	218	-1.99	1.76	0.76	5.674	1.211	0.706	0.0461	0.332	0.0395
CCP, un.	211	-2.20	1.55	0.80	5.662	1.249	0.705	0.0454	0.332	0.0394
Rule 2 - Credit Growth Rule										
LF, cou.	53	2.09	5.84	0.79	5.922	1.315	0.711	0.0509	0.332	0.0573
LF, un.	69	2.23	5.98	0.82	5.943	1.311	0.712	0.0490	0.333	0.0566
CCP, cou.	139	3.73	7.48	0.81	6.045	1.230	0.716	0.0434	0.334	0.0577
CCP, un.	135	3.75	7.50	0.81	6.041	1.232	0.716	0.0435	0.334	0.0569

No UMP: no unconventional monetary policy. LF: liquidity facilities. CCP: corporate credit policy. Cou.: country-specific. Un.: union-wide. κ_f: optimal feedback coefficient for liquidity facilities. κ_m: optimal feedback coefficient for credit policy. g: welfare gains in consumption equivalents in percent of steady-state consumption. Relative gain: difference in g to case without unconventional policy. International risk-sharing is measured as corr(λ_t, λ_t^*). Columns (5)-(7) and (9) display the stochastic steady state of the given variable.

Table B.6: *Optimal Simple Rules in a Symmetric Setup (Fully Diversified Portfolio, $\mu_A = 0.5$)*

	κ_f, κ_m (1)	g (2)	Rel. gain (3)	Risk-sharing (4)	K (5)	N (6)	C (7)	vol(C) (8)	L (9)	vol(L) (10)
No UMP	-	-0.10	-	0.98	5.648	1.428	0.707	0.0339	0.333	0.0208
Rule 1 - Credit Spread Rule										
LF, cou.	0	-0.10	0	0.98	5.648	1.428	0.707	0.0339	0.333	0.0208
LF, un.	0	-0.10	0	0.98	5.648	1.428	0.707	0.0339	0.333	0.0208
CCP, cou.	116	0.14	0.25	0.96	5.656	1.402	0.707	0.0288	0.333	0.0137
CCP, un.	76	-0.06	0.04	0.98	5.646	1.428	0.707	0.0294	0.333	0.0147
Rule 2 - Credit Growth Rule										
LF, cou.	30	0.57	0.68	0.93	5.692	1.396	0.708	0.0298	0.333	0.0230
LF, un.	43	0.61	0.71	0.98	5.697	1.395	0.708	0.0284	0.333	0.0296
CCP, cou.	152	1.06	1.16	0.96	5.739	1.356	0.709	0.0235	0.333	0.0488
CCP, un.	149	1.08	1.19	0.98	5.737	1.356	0.709	0.0234	0.333	0.0478

No UMP: no unconventional monetary policy. LF: liquidity facilities. CCP: corporate credit policy. Cou.: country-specific. Un.: union-wide. κ_f: optimal feedback coefficient for liquidity facilities. κ_m: optimal feedback coefficient for credit policy. g: welfare gains in consumption equivalents in percent of steady-state consumption. Relative gain: difference in g to case without unconventional policy. International risk-sharing is measured as corr(λ_t, λ_t^*). Columns (5)-(7) and (9) display the stochastic steady state of the given variable.

Table B.7: *Optimal Simple Rules in a Symmetric Setup (Fully Diversified Portfolio, $\mu_A = 0.5$; Only Capital Quality Shocks)*

B.4 Robustness Analysis with Respect to Higher Public Intermediation Costs

	κ_f, κ_m (1)	g (2)	Rel. gain (3)	Risk-sharing (4)	K (5)	N (6)	C (7)	vol(C) (8)	L (9)	vol(L) (10)
No UMP	-	-3.69	-	0.70	5.609	1.524	0.702	0.0606	0.331	0.0803
Rule 1 - Credit Spread Rule										
LF, cou.	17	-3.67	0.02	0.68	5.626	1.532	0.704	0.0575	0.332	0.0608
LF, un.	17	-3.67	0.02	0.67	5.625	1.533	0.703	0.0576	0.332	0.0610
CCP, cou.	50	-2.85	0.84	0.67	5.661	1.451	0.705	0.0528	0.332	0.0440
CCP, un.	59	-2.78	0.90	0.64	5.667	1.431	0.705	0.0529	0.332	0.0429
Rule 2 - Credit Growth Rule										
LF, cou.	23	1.13	4.82	0.69	5.912	1.337	0.710	0.0579	0.332	0.0639
LF, un.	26	1.05	4.74	0.68	5.899	1.343	0.710	0.0574	0.332	0.0621
CCP, cou.	50	3.03	6.71	0.71	5.992	1.279	0.714	0.0510	0.333	0.0557
CCP, un.	53	2.77	6.46	0.66	5.975	1.288	0.714	0.0518	0.333	0.0541

No UMP: no unconventional monetary policy. LF: liquidity facilities. CCP: corporate credit policy. Cou.: country-specific. Un.: union-wide. κ_f: optimal feedback coefficient for liquidity facilities. κ_m: optimal feedback coefficient for credit policy. g: welfare gains in consumption equivalents in percent of steady-state consumption. Relative gain: difference in g to case without unconventional policy. International risk-sharing is measured as corr(λ_t, λ_t^*). Columns (5)-(7) and (9) display the stochastic steady state of the given variable.

Table B.8: *Optimal Simple Rules in a Symmetric Setup (Higher Intermediation Costs, $\tau_1 = 0.000313$, $\tau_2 = 0.0031$)*

	κ_f, κ_m (1)	g (2)	Rel. gain (3)	Risk-sharing (4)	K (5)	N (6)	C (7)	vol(C) (8)	L (9)	vol(L) (10)
no UMP	-	-3.69	-	0.70	5.609	1.524	0.702	0.0606	0.331	0.0803
Rule 1 - Credit Spread Rule										
LF, cou.	0	-3.69	0.00	0.70	5.609	1.524	0.702	0.0606	0.331	0.0803
LF, un.	0	-3.69	0.00	0.70	5.609	1.524	0.702	0.0606	0.331	0.0803
CCP, cou.	23	-3.24	0.45	0.68	5.655	1.493	0.705	0.0552	0.332	0.0506
CCP, un.	26	-3.21	0.48	0.66	5.659	1.487	0.705	0.0553	0.332	0.0496
Rule 2 - Credit Growth Rule										
LF, cou.	13	0.03	3.71	0.69	5.891	1.356	0.708	0.0599	0.331	0.0712
LF, un.	13	0.02	3.71	0.70	5.867	1.365	0.708	0.0598	0.331	0.0713
CCP, cou.	23	2.11	5.80	0.70	5.944	1.313	0.712	0.0553	0.332	0.0580
CCP, un.	26	1.94	5.63	0.67	5.935	1.319	0.712	0.0551	0.332	0.0564

No UMP: no unconventional monetary policy. LF: liquidity facilities. CCP: corporate credit policy. Cou.: country-specific. Un.: union-wide. κ_f: optimal feedback coefficient for liquidity facilities. κ_m: optimal feedback coefficient for credit policy. g: welfare gains in consumption equivalents in percent of steady-state consumption. Relative gain: difference in g to case without unconventional policy. International risk-sharing is measured as corr(λ_t, λ_t^*). Columns (5)-(7) and (9) display the stochastic steady state of the given variable.

Table B.9: *Optimal Simple Rules in a Symmetric Setup (Higher Intermediation Costs, $\tau_1 = 0.000625$, $\tau_2 = 0.0062$)*

Appendix C

Appendix to Chapter 4

C.1 Further Tables

	γ_B in % (1)	γ_{RS} % (2)	Actual risk-sharing (3)	Potential risk-sharing (4)	Difference (4)-(3) (5)	corr(Ω, Λ) (6)
Only Capital Quality Shocks (ϵ_t^Ψ)						
Baseline banks	64	150	0.20	0.49	0.29	0.81
Lower spread	68	118	0.24	0.36	0.12	0.90
Lower leverage	78	131	0.30	0.45	0.15	0.76
Both lower	85	112	0.31	0.35	0.04	0.85
Only Technology Shocks (ϵ_t^A)						
Baseline banks	41	125	0.25	0.44	0.18	0.49
Lower spread	52	110	0.30	0.40	0.10	0.57
Lower leverage	51	120	0.26	0.41	0.15	0.51
Both lower	68	108	0.33	0.39	0.05	0.56
Only Net Wealth Shocks (ϵ_t^N)						
Baseline banks	496	414	-0.72	-0.69	0.03	-0.02
Lower spread	466	420	-0.66	-0.66	0.01	-0.00
Lower leverage	510	393	-0.76	-0.69	0.07	0.00
Both lower	477	398	-0.70	-0.67	0.03	0.01

Risk-sharing is measured as corr(λ, λ^*).

Table C.1: *Portfolio Choice and Risk-Sharing for Different Degrees of Financial Frictions under Different Shock Structures*

	γ_{HH} in % (1)	Risk-Sharing (2)
Baseline	741	0.997
Only capital quality shocks (ϵ_t^{Ψ})	748	1.000
Only technology shocks (ϵ_t^{A})	699	1.000

Risk-sharing is measured as corr(λ, λ^*).

Table C.2: *Optimal Risk-Sharing in Model without a Financial Friction*

Bibliography

AURAY, S., A. EYQUEM, AND X. MA (2016): "Banks, Sovereign Risk and Unconventional Monetary Policies," Working Paper 2014-10, Centre de Recherche en Économie et Statistique. 2, 31, 35

BASEL COMMITTEE ON BANKING SUPERVISION (2017): "Range of Practices in Implementing the Countercyclical Capital Buffer Policy," Implementation, Bank for International Settlements. 57

BRUEGEL, ed. (2017): *Eurosystem Liquidity*, Bruegel Datasets, Retrieved from: http://bruegel.org/publications/datasets/eurosystem-liquidity/ (15.08.2018). 29, 30

BRUNNERMEIER, M. K. (2009): "Deciphering the Liquidity and Credit Crunch 2007-2008," *Journal of Economic Perspectives*, 23, 77–100. 1

BRUNNERMEIER, M. K. AND Y. SANNIKOV (2015): "International Credit Flows and Pecuniary Externalities," *American Economic Journal: Macroeconomics*, 7, 297–338. 17, 73

BRZOZA-BRZEZINA, M., M. KOLASA, AND K. MAKARSKI (2015): "Monetary and Macroprudential Policy with Foreign Currency Loans," Working Paper Series 1783, ECB. 2, 35

CAHN, C., J. MATHERON, AND J.-G. SAHUC (2014): "Assessing the Macroeconomic Effects of LTROs," Working Paper 528, Banque de France. 41

CALVO, G. A. (1983): "Staggered Prices in a Utility-Maximizing Framework," *Journal of Monetary Economics*, 12, 383 – 398. 40, 95

CARNITI, E. (2012): "1. Banking Frictions and Integrated Financial Markets in a Two Country DSGE Model. 2. Unconventional Monetary Policy Coordination in a Two Country World with Banking Frictions." Ph.D. thesis, LUISS Guido Carli. 6, 7, 8, 18, 64, 65, 66

CHO, J.-O., T. F. COOLEY, AND H. S. E. KIM (2015): "Business Cycle Uncertainty and Economic Welfare," *Review of Economic Dynamics*, 18, 185–200. 29

Coeurdacier, N., R. Kollmann, and P. Martin (2010): "International Portfolios, Capital Accumulation and Foreign Assets Dynamics," *Journal of International Economics: Special Issue on International Macro-Finance*, 80, 100 – 112. 76

Coeurdacier, N. and H. Rey (2012): "Home Bias in Open Economy Financial Macroeconomics," *Journal of Economic Literature*, 51, 63–115. 18, 19, 64, 76, 84

Coeurdacier, N., H. Rey, and P. Winant (2011): "New Approaches for Modeling Risk in Macroeconomics. The Risky Steady State," *American Economic Review: Papers & Proceedings*, 101, 398–401. 17, 73

Cúrdia, V. and M. Woodford (2011): "The Central-Bank Balance Sheet as an Instrument of Monetary Policy," *Journal of Monetary Economics*, 58, 54–79. 1, 30

de Walque, G., F. Smets, and R. Wouters (2006): "An Estimated Two-Country DSGE Model for the Euro Area and the US Economy," Working paper presented at the 7th EABCN Workshop (Zurich, August 2006), Swiss National Bank. 47

Dedola, L., P. Karadi, and G. Lombardo (2013): "Global Implications of National Unconventional Policies," *Journal of Monetary Economics*, 60, 66–85. 1, 2, 6, 7, 8, 10, 14, 18, 22, 23, 28, 31, 44, 45, 64, 65, 66, 70

Dedola, L. and G. Lombardo (2012): "Financial Frictions, Financial Integration and the International Propagation of Shocks," *Economic Policy*, 27, 319–359. 1, 3, 6, 7, 18, 22, 23, 24, 25, 65

Del Negro, M., G. Eggertsson, A. Ferrero, and N. Kiyotaki (2011): "The Great Escape? A Quantitative Evaluation of the Fed's Liquidity Facilities," Staff Reports 520, Federal Reserve Bank of New York. 1

Devereux, M. B., O. Senay, and A. Sutherland (2014): "Nominal Stability and Financial Globalization," *Journal of Money, Credit and Banking*, 46, 921–959. 41

Devereux, M. B. and A. Sutherland (2007): "Solving for Country Portfolios in Open Economy Macro Models," Working Paper 07/284, IMF. 2, 8, 17, 18, 65, 66, 73, 74, 89

——— (2008): "Country Portfolios in Open Economy Macro Models," Working Paper 14372, NBER. 2, 8, 17, 18, 65, 66, 73, 74, 77, 89

——— (2009): "A Portfolio Model of Capital Flows to Emerging Markets," *Journal of Development Economics*, 89, 181–193. 16, 47, 72

——— (2011a): "Country Portfolios in Open Economy Macro Models," *Journal of the European Economic Association*, 9, 337–369. 2, 8, 17, 18, 65, 66, 73, 74, 77, 89

——— (2011b): "Evaluating International Financial Integration under Leverage Constraints," *European Economic Review*, 55, 427–442. 1

Devereux, M. B. and J. Yetman (2010): "Leverage Constraints and the International Transmission of Shocks," *Journal of Money, Credit and Banking*, 42, 71–105. 1, 3, 6, 9, 18, 33, 65, 67

Dmitriev, A. and I. Roberts (2013): "The Cost of Adjustment: On Comovement between the Trade Balance and the Terms of Trade," *Economic Modelling*, 35, 689 – 700. 14

Dräger, L. and C. R. Proaño (2018): "Cross-Border Banking and Macroprudential Policies in Asymmetric Currency Unions," *Macroeconomic Dynamics*, forthcoming. 1, 2, 35

Draghi, M. (2013): *The Role of Monetary Policy in Addressing the Crisis in the Euro Area*, Speech given at the "Room for discussion" of the Study Association SEFA and the Faculty of Economics and Business, Amsterdam, 15 April 2013, Retrieved from: http://www.ecb.europa.eu/press/key/date/2013/html/sp130415.en.html (22.08.2018). 3

ECB (2017): "The ECB's Corporate Sector Purchase Programme: Its Implementation and Impact," in *ECB Economic Bulletin, Issue 4*, 40–45. 29, 30

Engel, C. and A. Matsumoto (2009): "The International Diversification Puzzle When Goods Prices Are Sticky: It's Really about Exchange-Rate Hedging, Not Equity Portfolios," *American Economic Journal: Macroeconomics*, 1, 155–88. 24, 76

Evans, M. D. D. and V. Hnatkovska (2005): "Solving General Equilibrium Models with Incomplete Markets and Many Assets," Technical Working Paper 318, NBER. 17, 73

Fiore, F. D. and H. Uhlig (2011): "Bank Finance versus Bond Finance," *Journal of Money, Credit and Banking*, 43, 1399–1421. 72

Furlanetto, F. and M. Seneca (2014): "New Perspectives on Depreciation Shocks as a Source of Business Cycle Fluctuations," *Macroeconomic Dynamics*, 18, 1209–1233. 6

GERALI, A., A., S. NERI, S., L. SESSA, L., AND F. M. SIGNORETTI (2010): "Credit and Banking in a DSGE Model of the Euro Area," *Journal of Money, Credit and Banking*, 42, 107–141. 1

GERTLER, M. AND P. KARADI (2011): "A Model of Unconventional Monetary Policy," *Journal of Monetary Economics*, 58, 17–34. 1, 2, 6, 8, 13, 15, 16, 28, 30, 31, 32, 35, 38, 39, 43, 44, 47, 49, 50, 53, 64, 65, 66, 71, 72, 78, 80

GERTLER, M. AND N. KIYOTAKI (2011): "Financial Intermediation and Credit Policy in Business Cycle Analysis," in *Handbook of Monetary Economics*, ed. by B. M. Friedman and M. Woodford, Elsevier, vol. 3, chap. 11, 547–599. 1, 2, 6, 28, 30, 42, 64, 65, 72

GERTLER, M., N. KIYOTAKI, AND A. QUERALTO (2012): "Financial Crises, Bank Risk Exposure and Government Financial Policy," *Journal of Monetary Economics*, 59, Supplement, 17 – 34. 45, 47

GHILARDI, M. F. AND S. J. PEIRIS (2016): "Capital Flows, Financial Intermediation and Macroprudential Policies," *Open Economies Review*, 27, 721–746. 58, 81

GUERRIERI, L., M. IACOVIELLO, AND R. MINETTI (2012): "Banks, Sovereign Debt and the International Transmission of Business Cycles," Working Paper 18303, NBER. 1

HJORTSOE, I. (2016): "Imbalances and Fiscal Policy in a Monetary Union," *Journal of International Economics*, 102, 225 – 241. 10, 16, 34, 35, 46, 47, 67

IMBS, J. (2010): "The First Global Recession in Decades," *IMF Economic Review*, 58, 327–354. 1

JUILLARD, M. (2011): "Local Approximation of DSGE Models Around the Risky Steady State," wp.comunite 0087, Department of Communication, University of Teramo. 17, 73

JUILLARD, M. AND O. KAMENIK (2005): "Solving DSGE Models: Approximation About The Stochastic Steady State," Unpublished. 49

JUSTINIANO, A., G. E. PRIMICERI, AND A. TAMBALOTTI (2011): "Investment Shocks and the Relative Price of Investment," *Review of Economic Dynamics*, 14, 102–121, Special issue: Sources of Business Cycles. 6, 24

KAMINSKY, G. L. AND C. M. REINHART (2000): "On Crises, Contagion, and Confusion," *Journal of International Economics*, 51, 145–168. 7

KOLLMANN, R. (2012): "Limited Asset Market Participation and the Consumption-Real Exchange Rate Anomaly," *Canadian Journal of Economics*, 45, 566–584. 65

KOLLMANN, R., Z. ENDERS, AND G. J. MÜLLER (2011): "Global Banking and International Business Cycles," *European Economic Review*, 55, 407–426. 1

KOSE, M. A., E. S. PRASAD, AND M. E. TERRONES (2009): "Does Financial Globalization Promote Risk Sharing?" *Journal of Development Economics*, 89, 258–270. 3, 19, 64, 84

LANE, P. R. AND G. M. MILESI-FERRETTI (2007): "The External Wealth of Nations Mark II: Revised and Extended Estimates of Foreign Assets and Liabilities," *Journal of International Economics*, 73, 223–250. 1, 5, 63

——— (2010): "The Cross-Country Incidence of the Global Crisis," Working Paper 10/171, IMF. 7

LANG, J. H. AND P. WELZ (2017): "Measuring Credit Gaps for Macroprudential Policy," in *Financial Stability Review*, ECB, chap. B, 144–157. 58, 81

LESTER, R., M. PRIES, AND E. SIMS (2014): "Volatility and Welfare," *Journal of Economic Dynamics and Control*, 38, 17–36. 29

LEVINE, P. AND D. LIMA (2015): "Policy Mandates for Macro-Prudential and Monetary Policies in a New Keynesian Framework," Working Paper Series 1784, ECB. 58, 81, 82

LIU, Z., D. F. WAGGONER, AND T. ZHA (2011): "Sources of Macroeconomic Fluctuations: A Regime-Switching DSGE Approach," *Quantitative Economics*, 2, 251–301. 6, 24

LOMBARDO, G. AND A. SUTHERLAND (2007): "Computing Second-Order-Accurate Solutions for Rational Expectation Models Using Linear Solution Methods," *Journal of Economic Dynamics and Control*, 31, 515 – 530. 73

MACCHIARELLI, C., M. MONTI, AND A. VEDOLIN (2017): "The Corporate Sector Purchase Programme (CSPP): Effectiveness and Challenges Ahead," In-Depth Analysis 2017-03, European Parliament. Directorate General for Internal Policies. 61

MAGGIORI, M. (2017): "Financial Intermediation, International Risk Sharing and Reserve Currencies," *American Economic Review*, 107, 3038–3071. 4, 64, 65

MEH, C. A. AND K. MORAN (2010): "The Role of Bank Capital in the Propagation of Shocks," *Journal of Economic Dynamics and Control*, 34, 555 – 576. 1

Nuguer, V. (2016): "Financial Intermediation in a Global Environment," *International Journal of Central Banking*, 12, 291–344. 1, 31

Nuntramas, P. (2011): "Revisiting the Consumption-Real Exchange Rate Anomaly in a Model with Non-Traded Goods," *Journal of International Money and Finance*, 30, 428–447. 19, 75

Pfeiffer, J. (2016): *Welfare Cost of Business Cycles*, Forum entry from Dec. 2016, Dynare forum, Retrieved from https://forum.dynare.org/t/welfare-cost-of-business-cycles/3802 (15.08.2018). 49

——— (2018): *Where is the Stochastic Steady State in Dynare?*, Forum entry from Jan. 2018, Dynare forum, Retrieved from https://forum.dynare.org/t/where-is-the-stochastic-steady-state-in-dynare/2370 (15.08.2018). 52

Poutineau, J.-C. and G. Vermandel (2015): "Cross-Border Banking Flows Spillovers in the Eurozone: Evidence from an Estimated DSGE Models," *Journal of Economic Dynamics and Control*, 51, 378 – 403. 1, 2, 35, 47

Praet, P. (2017): *The ECB's Monetary Policy: Past and Present*, Speech by Peter Praet, Member of the Executive Board at the Febelfin Connect event, Brussels/Londerzeel, 16 March 2017, Retrieved from https://www.bis.org/review/r170317a.htm (22.08.2018). 29

Primiceri, G., E. Schaumburg, and A. Tambalotti (2006): "Intertemporal Disturbances," Working Paper 12243, NBER. 47

Rabitsch, K., S. Stepanchuk, and V. Tsyrennikov (2015): "International portfolios: A comparison of solution methods," *Journal of International Economics*, 97, 404 – 422. 35

Rose, A. K. and M. M. Spiegel (2010): "Cross-Country Causes and Consequences of the 2008 Crisis: International Linkages and American Exposures," *Pacific Economic Review*, 15, 340–363. 7

Sanjani, M. T. (2014): "Financial Frictions and Sources of Business Cycle," Working Paper 14/194, IMF. 6, 24

Schmitt-Grohé, S. and M. Uribe (2003): "Closing Small Open Economy Models," *Journal of International Economics*, 61, 163–185. 8, 9, 10, 32, 33, 34, 66

——— (2004): "Optimal Simple and Implementable Monetary and Fiscal Rules," Working Paper 10253, NBER. 49

Schwanebeck, B. (2017): "Unconventional Monetary Policy in a Financially Heterogenous Monetary Union," Discussion Paper in Economics 41, MAGKS. 31

Sorensen, B. E., Y.-T. Wu, O. Yosha, and Y. Zhu (2007): "Home Bias and International Risk Sharing: Twin Puzzles Separated at Birth," *Journal of International Money and Finance*, 26, 903–918. 64

Tille, C. and E. van Wincoop (2010): "International Capital Flows," *Journal of International Economics*, 80, 157–175. 17, 73

Tischbirek, A. (2016): "Unconventional Monetary Policy in a Currency Union with Segmentation in the Market for Government Debt," Working Paper, University of Lausanne. 3, 31

Uzawa, H. (1968): "Time Preference, the Consumption Function and Optimal Asset Holdings," in *Value, Capital and Growth: Papers in Honour of Sir John Hicks*, ed. by J. N. Wolfe, Edinburgh University Press, 485–504. 8, 32

van Wincoop, E. (1999): "How Big are Potential Welfare Gains from International Risksharing?" *Journal of International Economics*, 47, 109 – 135. 76

Živanović, J. (2017): "1. A Structural Empirical Analysis of the External Finance Premium. 2. Corporate Debt Composition and Business Cycles. 3. An Optimal Policy Mix for Segmented Credit Markets," Ph.D. thesis, Humboldt-Universität zu Berlin. 72

Yao, W. (2012): "International Business Cycles and Financial Frictions," Working Paper 1012-19, Bank of Canada. 3, 6, 7, 18, 22, 23, 25, 65

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Ich versichere, die von mir vorgelegte Dissertation selbständig und ohne unerlaubte Hilfe und Hilfsmittel angefertigt, sowie die benutzten Quellen und Daten anderen Ursprungs als solche kenntlich gemacht zu haben.

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Berlin, 31. August 2018

Johanna Krenz